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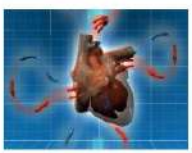

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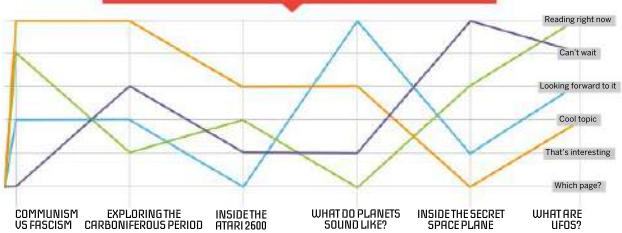
One of the most exciting developments in recent history for both UFO spotters and the scientific community came in 2020, when the Pentagon officially released three videos of aerial objects that were recorded by military pilots flying fighter aircraft. The US government couldn't explain what the fast-moving objects in the videos were, and nor can anyone else. It's stoked the flames of wild theories from those who believe we're being visited by aliens, but has also put a spotlight on the ordinary scientific reasons behind most UFO sightings. In this issue of **How It Works**, we explore and explain the many phenomena that can lead to people believing they have witnessed extraterrestrial technology. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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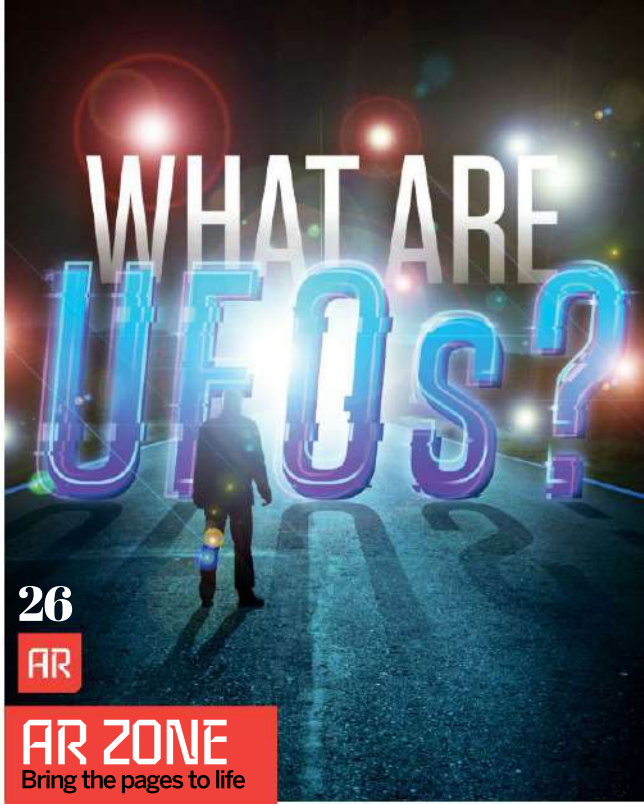

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MEET THIS ISSUE'S EXPERTS

ANDY EXTANCE

Andy is a science writer. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

DR ANDREW MAY

Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

VICTORIA WILLIAMS

Evolutionary biologist and science writer Vicky is fascinated by the natural world and is happiest when she's in the outdoors.

JO ELPHICK

Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

MARK SMITH

A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

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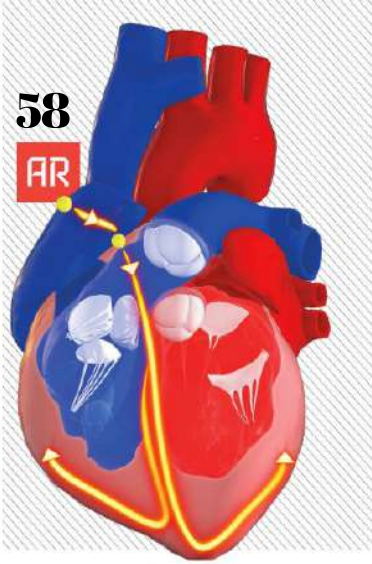

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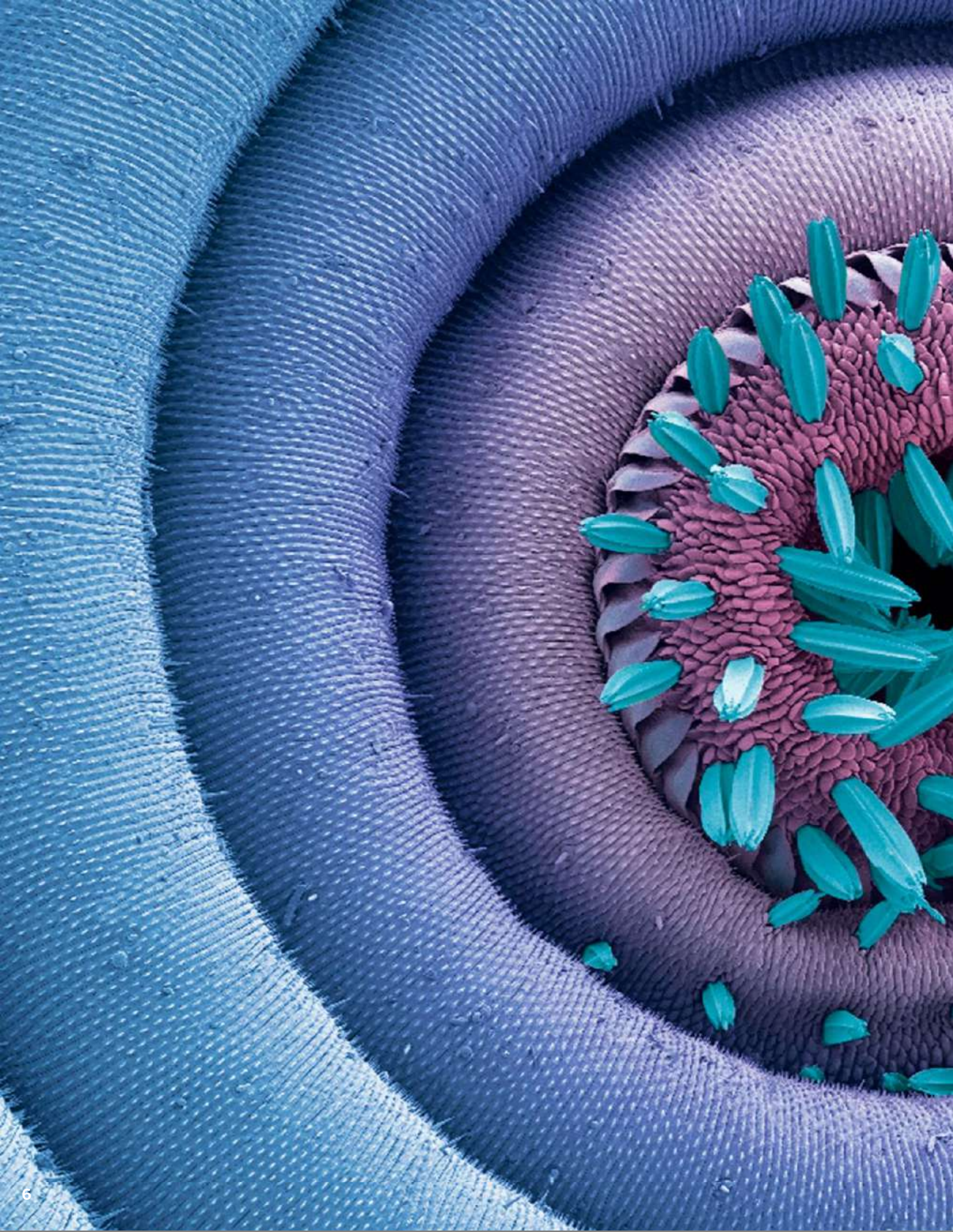

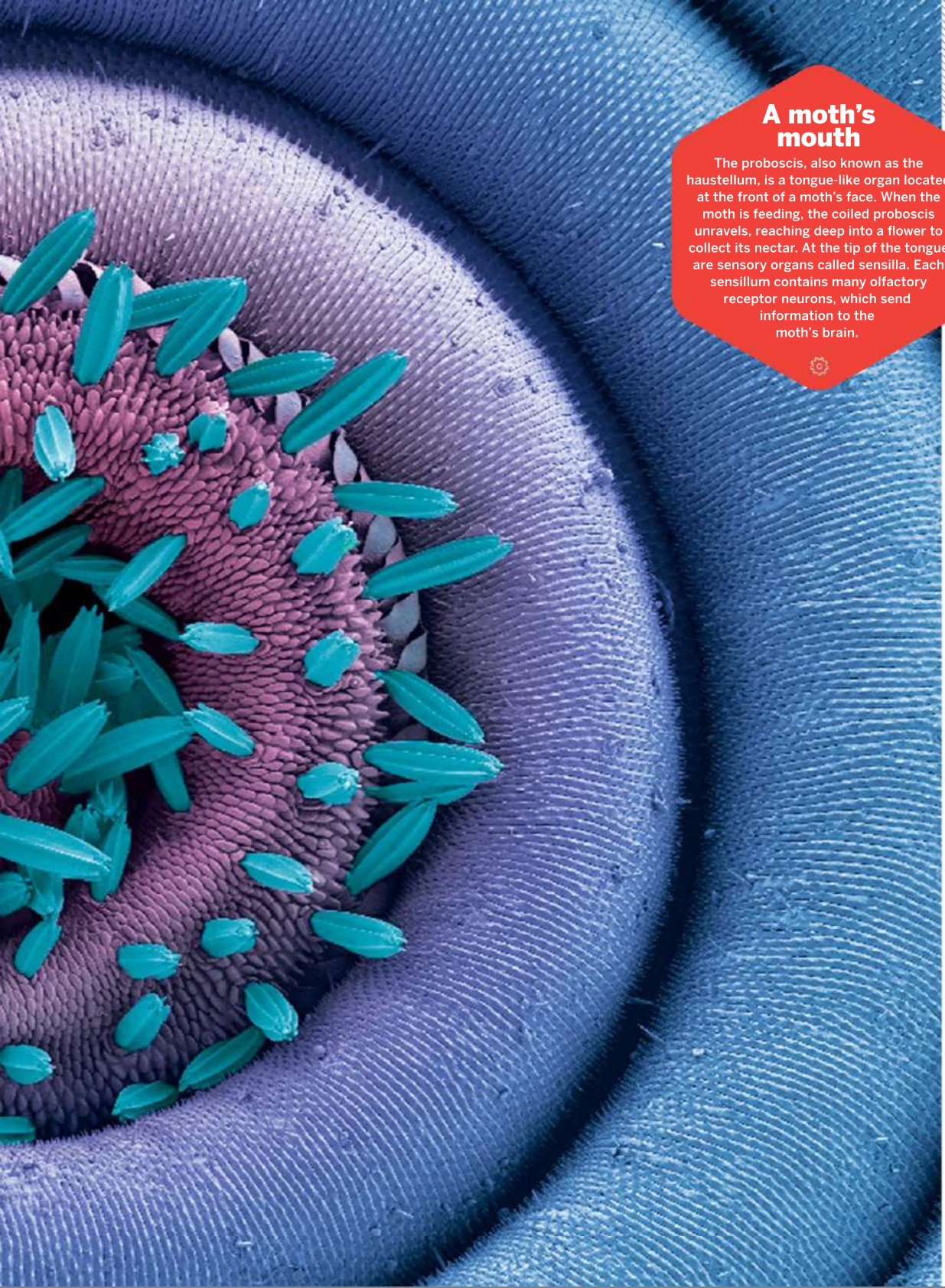

A moth's mouth

The proboscis, also known as the haustellum, is a tongue-like organ located at the front of a moth's face. When the moth is feeding, the coiled proboscis unravels, reaching deep into a flower to collect its nectar. At the tip of the tongue are sensory organs called sensilla. Each sensillum contains many olfactory receptor neurons, which send information to the moth's brain.

© Getty

Devil ray migration

This aerial view shows a group of Munk's devil rays (*Mobula munkiana*) on a migratory journey through the Sea of Cortés, Baja California. The migration of these rays is typically driven by temporary changes in water temperature and the distribution of planktonic crustaceans for food. This species is known to breach the water's surface, like dolphins, which is thought to be a form of courtship display.

© Getty

Where ice and sand meet

Khar Nuur is a lake surrounded by sparsely vegetated dunes and snow-capped mountains in the Great Lakes Hollow in western Mongolia. Khar Nuur is around 1,900 metres above sea level and is exposed to the cold air that moves across Mongolia from Serbia. This causes water temperatures to drop below freezing during winter, and the surface can remain frozen well into April.

© NASA/JSC

Mars selfie

Here is NASA's Curiosity rover atop the Vera Rubin ridge, snapping a selfie and capturing the barren landscape of the Red Planet. Directly behind Curiosity's mast is the 3.4-mile-high Mount Sharp, which the rover has now reached. Curiosity landed on Mars back in 2012 and has since been surveying the surface in hope of finding signs of life. The rover is currently on a drill campaign around Gale crater to collect rock samples for analysis.

© NASA/JPL-Caltech/MSSS

SPACE

Massive comet is headed our way

WORDS BRANDON SPECKTOR

An illustration of the massive comet Bernardinelli-Bernstein

An enormous comet, possibly the largest one ever detected, is barrelling towards the inner Solar System, with an estimated arrival time of ten years from now. The comet, known as Bernardinelli-Bernstein, or officially C/2014 UN271, is at least 62 miles across – about 1,000 times more massive than a typical comet. It's so large that astronomers previously mistook it for a dwarf planet. But a closer analysis of the object revealed that it was moving rapidly through the Oort Cloud, a vast scrapyard of icy rocks, billions of miles from Earth. The object appeared to be headed our way, and it even had a glowing tail, or coma, behind it, a clear indication of an icy comet approaching the relatively warm inner Solar System.

Now researchers have studied the massive comet in more detail, and they have new estimates about its journey towards the Sun. For starters, the enormous rock poses no threat to Earth. Right now, Bernardinelli-Bernstein (BB) is cruising through the Oort Cloud at about 29 times the distance between Earth and the Sun – or 29 astronomical units (AU). The comet's closest approach to Earth will occur sometime in the year 2031, when scientists predict the comet will swoop within 10.97 AU of the Sun, putting it just outside of Saturn's orbit.

> "The enormous rock poses no threat to Earth"

While that's far enough from Earth that humans won't be able to see the comet without telescopes, it's considerably closer than the rock's last visit to our part of the Solar System. After modelling the comet's trajectory, the researchers also calculated that comet BB made its last approach 3.5 million years ago, coming within 18 AU of the Sun. Since then, the comet travelled as far as 40,000 AU away, deep into the mysterious Oort Cloud.

We owe our current view of the large, distant comet to the Dark Energy Survey (DES), a project to study the expansion of the universe which ran between August 2013 and January 2019. During the survey, astronomers mapped 300 million galaxies in the southern sky, discovering more than 800 previously unknown objects beyond the orbit of Neptune. The Bernardinelli-Bernstein comet was one of those objects.

Researchers have plenty of time to study the massive comet as it soars ever closer to Earth over the next decade. Getting a closer look at the rock could help scientists understand a bit more about the chemical composition of the early Solar System, as comets from deep in the Oort Cloud are thought to be relatively unchanged since they were booted away from the Sun billions of years ago. With millions of years separating the comet's next close approach from its following one, it'll be a once-in-a-lifetime brush with the early Solar System.

ANIMALS

American bumblebee could be endangered

WORDS **BEN TURNER**

The American bumblebee (*Bombus pensylvanicus*) population has plummeted by 89 per cent over the past 20 years, and an endangered species listing could be imminent. The US Fish and Wildlife Service will conduct a one-year review, after which the species could become protected under the Endangered Species Act (ESA), which provides a legal framework for safeguarding imperilled species from extinction.

The American bumblebee, a vital pollinator, has vanished from eight US states – Maine, New Hampshire, Rhode Island, Vermont, Idaho, North Dakota, Oregon and Wyoming – and in New York state the species has experienced a population decline of 99 per cent. In 19 other states across the Southeast and Midwest, populations have dropped by more than 50 per cent. The bumblebee's decline is attributed to habitat destruction, exposure to disease and pesticides, climate change, loss of genetic diversity and competition with non-native bees. In fact, the states with the largest declines in American bumblebee populations have seen the largest quantified increase in the use of pesticides.

Research has shown that chemical pesticides, such as neonicotinoids, that are commonly sprayed over agricultural land can disrupt various bees' natural homing systems; make them more susceptible to parasites, such as the varroa mite (*Varroa destructor*); and interfere with their 'waggle dance', the butt-shaking method of bee communication. Research on buff-tailed bumblebees (*Bombus terrestris*) has found that neonicotinoids disrupted the bees' natural sleep patterns, reducing their daytime foraging opportunities and potentially limiting a colony's ability to grow. If American bumblebees are placed under the protection of the ESA, developers and farmers who kill the insects could incur legal liability, including fines each time a protected animal is killed.

Did you know? The ESA became effective in 1973

"The implications could be really significant," Keith Hirokawa, an environmental law professor at Albany Law School, said. "A far-reaching solution would be a fundamental change in the way we build our agricultural operations" to protect the bees' habitat from further damage.

If the American bumblebee is added to the list, it would become the third species in the Apidae family in the continental US to be officially registered as an endangered species, alongside the rusty-patched bumblebee (*Bombus affinis*) and the presumed-extinct Franklin's bumblebee (*Bombus franklini*), the last sighting of which was in Oregon in 2006.

An American bumblebee on fresh spring buds in New Hampshire

Hospital treatment left this patient with cement in his heart

HEALTH

CEMENT FOUND IN MAN'S HEART

WORDS **RACHAEL RETTNER**

A man's chest pain had an unusual cause: a ten-centimetre piece of cement in his heart, which travelled through his bloodstream after a medical procedure. The 56 year old went to the emergency room after he experienced chest pain and difficulty breathing for two days. A week earlier he had undergone a spinal procedure to treat a vertebral compression fracture, a painful condition in which part of a spine bone collapses into itself, often as a result of osteoporosis or bone weakening. The man received a kyphoplasty, where doctors inject a special type of cement into the vertebra to restore its proper height and keep it from collapsing.

Kyphoplasty is generally considered safe – less than two per cent of people experience a complication. But one risk is that the cement leaks from the bone into other areas, causing a blockage, or 'embolism', of a blood vessel. This is what happened here: the cement leaked from the bone into his veins, where it hardened and embolised, travelling to his heart.

The man had an X-ray and CT scan, which showed a foreign body in his heart. He underwent emergency heart surgery, during which doctors found a thin, sharp piece of cement that had torn through the right upper chamber of his heart and punctured his right lung. They removed the embolism, measuring 10.1 centimetres. Doctors then repaired the tear. He had no complications, and a month later was nearly fully recovered.

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An image taken from the International Space Station in 2011 shows earthshine on the Moon

PLANET EARTH

Climate change is making Earth dimmer

WORDS **MEGHAN BARTELS**

Earth is reflecting less light as its climate continues to change. A beautiful phenomenon connects climate and brightness: clouds. Clouds are a notoriously complicated piece of the climate puzzle. Scientists struggle to model how clouds will respond to climate change and how those responses in turn will shape the future climate. But scientists behind a new study think that the reflectivity finding hinges on the dynamics of clouds over the Pacific Ocean.

The research relies on two decades' worth of observations of a phenomenon called 'earthshine', which is the light that Earth reflects onto the surface of the dark side of the Moon, combined with satellite observations of Earth's reflectivity, or albedo, and the Sun's brightness. Different features on Earth reflect different amounts of light: the oceans very little, and land about twice as much. Meanwhile, clouds reflect about half the sunlight that hits them, and snow and ice reflect the majority of light they receive.

Scientists at Big Bear Solar Observatory in Southern California have been studying how earthshine fluctuates since 1998, looking for changes at time scales from daily to decadal. However, the researchers note that these measurements are only relative, and call for more robust observations.

In the new research, scientists combined that data with observations from NASA's Clouds and the Earth's Radiant Energy System (CERES) project, which has been operating since 1997 with instruments on a host of NASA and National Oceanic and Atmospheric Administration (NOAA) satellites. Researchers used two datasets to assess how Earth's brightness has been changing. Over the full two-decade span, the amount of light Earth reflected dropped about 0.5 per cent, or about half a watt less light per square metre. Most of the change comes in the last three years of the earthshine dataset, which the researchers analysed through 2017; the CERES data continues until 2019, and shows an even starker decline at its end.

And during that time, the brightness of the Sun – which went through two periods of maximum activity and one quiet period during the course of the study – didn't meaningfully connect to the dip in reflectance. Therefore a change in the amount of light Earth is reflecting must come from a change in Earth itself. In particular, the CERES data noted a loss of bright low-altitude clouds over the eastern Pacific Ocean off the west coast of the Americas, where scientists are also registering stark temperature increases at the ocean surface.

And because light not reflected out to space is trapped in the Earth system, the change in brightness also has implications for the future of climate, potentially increasing the pace of human-caused climate change.

PLANET EARTH

EXPLORERS ADD EIGHT MILES TO RECORD-BREAKING CAVE

WORDS **LAURA GEGGEL**

The longest known cave system just set a new record after surveyors spent hours mapping an additional eight miles of the passageways at Mammoth Cave National Park in Kentucky. The corridors now measure a whopping 420 miles in length. Mapping the cave system was a huge undertaking, carried out by volunteers at the Cave Research Foundation (CRF), a Kentucky-based nonprofit, and other locals, including those from the Central Kentucky Karst Coalition.

"Many of the cave trips are long and arduous, involving climbing, vertical exposure, squeezes, crawlways, water and mud," said Karen Willmes of the CRF. "After the trip, cartographers turn the data collected on the cave trip into a map. Other volunteers provide surface support. It's a first-rate effort for a world-class cave, and we're proud to be a part of it."

This isn't the first time that the system has 'grown'. It entered the record books in 1969 with a total of 65 miles of documented passageways. During a 14-hour survey in September 1972, CRF cavers discovered a connection between the Mammoth Cave system and Flint Ridge, bringing Mammoth Cave's total known distance to 144 miles. Since then, additional CRF surveys have added mileage to the Mammoth Cave system, including the discovery of connections between it and smaller caves, such as Proctor Cave, Roppel Cave and Morrison Cave.

Inside the Mammoth Cave National Park area

ANIMALS

Vegetarian ants have steak-knife teeth

WORDS JOANNA THOMPSON

Tiny arthropods such as ants, spiders and scorpions routinely bite, sting or otherwise pierce tough material like wood and skin. Recent research has shed light on what gives one group of leafcutter ants (*Atta cephalotes*) their biting edge. Using powerful microscopes, scientists have discovered a web of zinc atoms woven into the biological structure of the ants' jaws, lending them the durability of stainless-steel knives. This smooth distribution of zinc allows the edge of the ants' teeth to form a fine point, and keeps them sharp for a long time.

"The tiny animals who had this material, their muscles are microscopic compared to ours," said Robert Schofield, a biophysicist at the University of Oregon. The trick is that ants and other metal-mouthed arthropods leverage their sharp chompers to apply precisely the right amount of cutting force to slice through leaves or hide. Ant teeth contain a lot of zinc, but it remained unclear how those metal atoms were arranged, and how that helped the ants' bite. By examining the material make-up of leafcutter ant teeth under an ion-beam microscope before and after biting, the researchers were able to calculate the hardness, sharpness and durability of the teeth.

The tiny, serrated 'teeth' lining the inside edge of an ant's mandible are coated in a smooth blend of proteins crisscrossed with zinc. This material, known as a 'heavy element biomaterial', easily matches human tooth enamel for strength. It also makes an ant's tooth much better for slicing and dicing, since the blocky calcium phosphate crystals found in enamel can't form extremely sharp edges. That would be like trying to fashion a knife "out of chunks of gravel", Schofield said. Zinc, however, does not form blocky crystals; instead it stays evenly distributed throughout the protein mixture. That fine consistency allows for the sharp edges of the teeth.

Metallic reinforcements don't stop with ant teeth. Other invertebrates also weave zinc or a similar metal, manganese, into their tiny toolkits. Schofield and his team found that giant clam worms pack jaws infused with up to 18 per cent zinc. Similarly, scorpion stings and spider fangs employ a mix of zinc and manganese atoms to ensure that these slender, needle-like structures can puncture tough flesh without breaking.

A leafcutter ant (*Atta cephalotes*) using its metal-laced mandibles to cut through a leaf

© Alamy / Getty / NASA

Data collected from Laotian bats is strengthening the case for a COVID-19 natural origin

HEALTH

COVID relative found in Laos bats

WORDS **RACHAEL RETTNER**

Researchers have discovered coronaviruses lurking in Laotian bats which appear to be the closest known relatives to SARS-CoV-2, the virus that causes COVID-19, found to date. In a new study, researchers from the Pasteur Institute in France and the University of Laos captured 645 bats from limestone caves in northern Laos and screened them for viruses related to SARS-CoV-2. They found three viruses, which they dubbed BANAL-52, BANAL-103 and BANAL-236, that infected horseshoe bats and shared more than 95 per cent of their overall genome with SARS-CoV-2.

One of the viruses, BANAL-52, was 96.8 per cent identical to SARS-CoV-2. That makes BANAL-52 more genetically similar to SARS-CoV-2 than any other known virus. Previously, the closest known relative to SARS-CoV-2 was RaTG13, which was found in horseshoe bats in 2013 and shares 96.1 per cent of its genome with SARS-CoV-2.

What's more, all three of the newly discovered viruses are more similar to SARS-CoV-2 in a key part of their genome, called the receptor-binding domain (RBD), than other known viruses. The RBD is the part of the virus that allows it to bind to host cells. With SARS-CoV-2, the RBD binds to a receptor known as ACE2 on human cells, and the virus uses this receptor as a gateway into cells. Critically, the new study found that BANAL-52, BANAL-103 and BANAL-236 can bind to ACE2 and use it to enter human cells.

Other candidates proposed as ancestors of SARS-CoV-2 found in bats, including RaTG13, haven't been able to do this. The three viruses could bind to ACE2 about as well as early strains of SARS-CoV-2 found in Wuhan. These findings add to the evidence that SARS-CoV-2 had a natural origin, rather than escaping from a lab.

Did you know?
A disease passed to humans from animals is 'zoonotic'

"The receptor-binding domain of SARS-CoV-2 looked unusual when it was first discovered because there were so few viruses to compare it to," Edward C. Holmes, an evolutionary biologist at the University of Sydney, who wasn't involved in the new research, said.

"Now that we are sampling more from nature, we are starting to find these closely related bits of gene sequence," Holmes said. The findings support the hypothesis that SARS-CoV-2 resulted from a recombination of viral sequences existing in horseshoe bats.

Still, even though the newly discovered viruses are closely related to SARS-CoV-2, all three viruses lack a sequence for what is known as the 'furin cleavage site', which is seen in SARS-CoV-2 and aids the virus' entry into cells. This means that in order to better understand the origins of SARS-CoV-2, further research is needed to show how and when the furin site was introduced.

SPACE

SCIENTISTS PINPOINT THE AGE OF MOLTEN 'EINSTEIN RING'

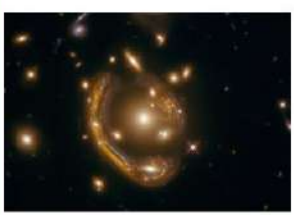
WORDS **ELIZABETH HOWELL**

New science from a stunning 2020 Hubble image illuminates the story behind a shining loop of light. The circle, also called an Einstein ring, came about due to a galactic-scale illusion. The galaxy this so-called 'molten ring' curls around is called GAL-CLUS-022058s and is located in the southern constellation of Fornax.

The big ring is actually a light smear created by a lensing effect that occurs when a foreground object with strong gravity magnifies the light of a more distant galaxy behind it. New research suggests that we are seeing the galaxy in the ring as it was about 9 billion years ago, when the universe was only about one-third its present age.

Back when the photo was released, scientists said this was one of the most complete Einstein rings ever catalogued. Astronomers dug up archival data gathered by the European Southern Observatory's Very Large Telescope to calculate the galaxy's distance at 9.4 billion light years. Further analysis allowed the team to examine stellar clumps of matter in the lensed galaxy, providing hints to its evolution.

"The extremely high rate of star formation in the brightest and very dusty early galaxies saw stars being born at a rate a thousand times faster than occurs within our own galaxy. This could help explain the rapid buildup of present-day giant elliptical galaxies," said Hubble officials.



A Hubble Space Telescope image shows one of the most complete Einstein rings scientists have studied to date

A massive iceberg was calved from the Larsen C Ice Shelf in 2017

PLANET EARTH

Melting 'glue' sent enormous iceberg to its doom

WORDS **YASEMIN SAPLAKOGLU**

The thinning of an icy 'glue' that holds fractured ice together may drive ice shelf collapse in Antarctica. Ice shelves are massive stretches of ice that build up over many thousands of years. But warming air and rising ocean temperatures have been driving ice shelves to disintegrate. Many of Antarctica's ice shelves have fractured or collapsed in the past couple of decades, but exactly what's accelerating the ice loss has been unclear.

To figure this out, a group of glaciologists zoomed in on rifts on Antarctica's Larsen C Ice Shelf, which calved a city-sized iceberg called A68 in July 2017. The split of A68, an iceberg approximately 2,240 square miles in area, reduced the size of Larsen C by 12 per cent. Larsen C is the third ice shelf on Antarctica's western peninsula to undergo massive ice loss in the past two decades.

The prevailing theory was that these splits were happening due to a process known as hydrofracturing, in which pools of melted ice on the surface of ice shelves seep through the cracks and expand once they freeze again. "But that theory fails to explain how iceberg A68 could break from the Larsen C Ice Shelf in the dead of the Antarctic winter when no melt pools were present," said Eric Rignot, a professor of Earth system science at the University of California, Irvine.

Rignot and his colleagues analysed hundreds of rifts, or fractures, in the Larsen C Ice Shelf using a model of ice sheets and sea-level changes developed by NASA, as well as data from satellites and research aircraft. They zoomed in on 11 cracks and modelled three melting scenarios. Two of the three scenarios focused on the role of 'melange', a mix of windblown snow, frozen seawater and ice shelf fragments that exists inside and around rifts and typically works to seal the fractures.

In the first scenario, the glaciologists modelled what would happen if the ice shelf thinned due to melting. In the second they modelled what would happen if the ice melange thinned, and in the third they modelled what would happen if both the ice shelf and the melange thinned. Their simulations showed that the thinning of the melange controlled the rate at which the rift opened.

If the ice shelf thinned but the melange remained just as thick, the rift widening slowed down with time. In other words, the melange acted as a 'healing' glue, fusing parts of the cracks. If both the ice shelf and the melange thinned, rift widening also slowed, but not as much as it did in the first scenario. If the ice shelf remained the same but the melange thinned, as in the second scenario, the average annual rate of rift widening increased from 76 to 112 metres.

Like sea ice, melange is vulnerable to the effects of warming oceans and rising air temperatures. "The melange is thinner than ice to begin with," said Eric Larour, a NASA Jet Propulsion Laboratory research scientist. Just 10 to 20 metres of melange thinning is enough to reactivate a rift, or start to unzip it and trigger a major calving event. Reactivating a rift can trigger ice shelves to retreat decades before water ponding would cause hydrofractures on the ice sheet surface.

© Getty / ESA-Hubble & NASA/S. Jha/Acknowledgement: L. Shatz / Joshua Stevens using Landsat data from the U.S. Geological Survey

Cassowaries are considered one of the world's most dangerous birds

HISTORY

Prehistoric people raised deadly cassowaries

WORDS JOANNA THOMPSON

New research suggests that the relationship between humans and cassowaries dates back to the Late Pleistocene era, several thousand years before humans domesticated chickens and geese. "And this is not some small fowl," said Kristina Douglass, an archaeologist at Penn State University. "It's a huge, ornery, flightless bird that can eviscerate you – most likely the dwarf variety that weighs 20 kilograms."

By examining the remains of ancient cassowary eggshells, Douglass and an international team of researchers determined that some 18,000 years ago, people in New Guinea were collecting, hatching and possibly raising cassowary chicks, which the researchers consider a sophisticated food-gathering technique. This represents the earliest known evidence of intentional bird rearing.

Using a combination of 3D imaging, computer modelling and egg morphology, the scientists examined over 1,000 fragments of cassowary eggshells dating to between 6,000 and 18,000 years ago. "We used that approach to see whether or not there was any pattern in terms of when people were harvesting cassowary eggs," said Douglass. "We found that there was a pattern, and that people were harvesting eggs preferentially in the later stages of development."

People would have kept these eggs for one of two purposes: to eat them or to raise the hatched chicks for their meat and feathers. Like geese, cassowary chicks imprint on the first creature they see. That makes them oddly ideal for human rearing, a practice that continues in parts of New Guinea to this day. Though Douglass and her team didn't find evidence of ancient people penning cassowaries, it's something they plan to look for in the future.

Cassowaries and their eggs are valuable resources for New Guineans. Historically, cassowary tibiotarsae, the upper part of the bird's leg, were used to fashion bone daggers for hunting. Today their feathers are prized for ornamentation, and the birds remain an important source of meat. But these striking birds, which can reach nearly 1.8 metres tall and 54 kilograms, are also incredibly dangerous.

"They have these really large claws. And if they feel threatened, they will use them," Douglass said. A frightened or territorial cassowary can lash out with a kick powerful enough to eviscerate a medium-size – or even human-size – mammal. Cassowaries do occasionally kill humans, including a man in Florida who was lethally attacked by a cassowary he kept on his farm in 2019. Even so, these instances are exceedingly rare.

ANIMALS

MOUNTAIN GOAT KILLS GRIZZLY BEAR WITH ITS HORNS

WORDS HARRY BAKER

After being attacked by a female grizzly bear, a very fortunate mountain goat seems to have fought back, using its horns to impale the furry predator. Hikers discovered the body of the 70-kilogram grizzly (*Ursus arctos horribilis*) just off a popular Canadian hiking route on 4 September. Park rangers quickly airlifted the carcass away from the trail to make sure that it didn't attract additional predators.

Officials initially weren't sure what had killed the female grizzly, which appeared to have been stabbed by something around the neck and armpit. A necropsy was carried out on the remains, revealing a surprising culprit. "The necropsy subsequently confirmed that the wounds incurred before death were consistent with the size and shape of mountain goat horns," David Laskin, a wildlife ecologist at Parks Canada, said.

The locations of the wounds suggest that the goat, as it was being attacked, was able to pierce the bear with its horns. "When grizzly bears attack, they tend to focus on the head, back of the neck and the shoulders of the prey, and it's usually from above, so the defensive response of the mountain goat would be to protect itself using its sharp horns," Laskin said. "I guess the mountain goat was successful in this instance and turned the tables on the grizzly."

A mountain goat (*Oreamnos americanus*) with its razor-sharp horns, used for self-defence

SPACE

Rare three-sun planet may lurk in Orion's nose

WORDS BRANDON SPECKTOR

There's now even more evidence that a bizarre star system perched on the constellation Orion's nose may contain the rarest type of planet in the known universe: a single world orbiting three suns simultaneously. The star system, known as GW Orionis (or GW Ori) and located about 1,300 light years from Earth, makes a tempting target for study. With three dusty, orange rings nested inside one another, the system looks like a giant bullseye in the sky. At the centre of that bullseye live three stars: two locked in a tight binary orbit with each other and a third swirling widely around the other two.

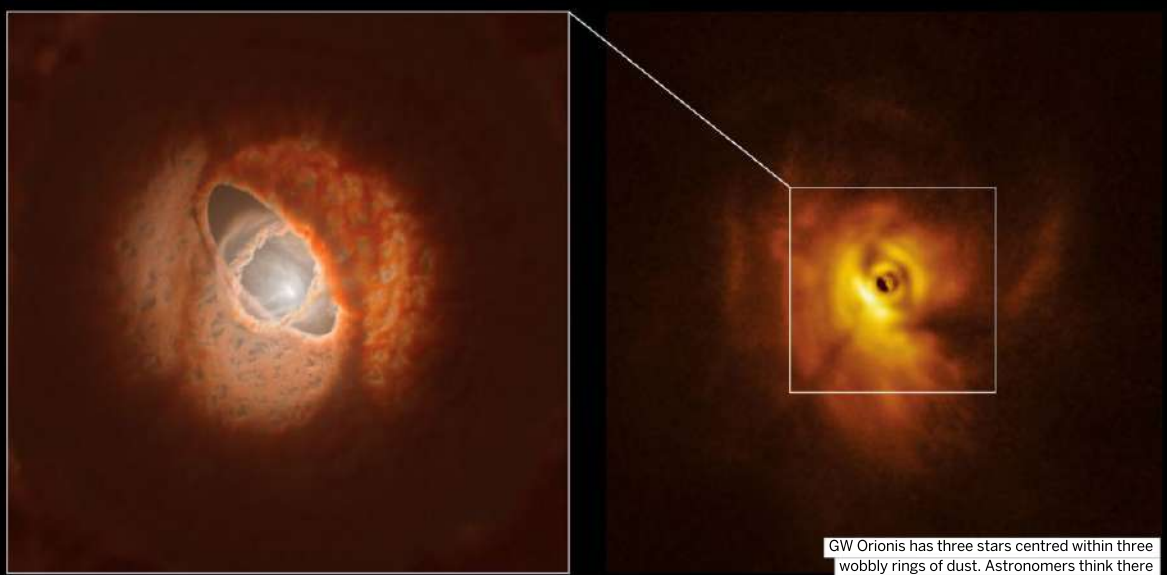
Triple-star systems are rare in the cosmos, but GW Ori gets even weirder the closer astronomers look. In 2020, researchers took a close look at GW Ori with the Atacama Large Millimeter/submillimeter Array (ALMA) telescope in Chile and discovered that the system's three dust rings are actually misaligned with one another, with the innermost ring wobbling wildly in its orbit.

The researchers proposed that a young planet – or the makings of one – could be throwing off the gravitational balance of GW Ori's intricate triple-ring arrangement. If the detection is confirmed, it would be the first triple-sun planet, or 'circumtriple' planet, in the known universe. Research published in September 2021 offers fresh evidence of that rare planet's existence. Scientists conducted 3D simulations to model how the mysterious gaps in the star system's rings could have formed based on observations of other dust rings, or 'protoplanetary discs', elsewhere in the universe.

Did you know? Up to 85 per cent of stars have a companion

The team tested two hypotheses: either the break in GW Ori's rings formed from the torque applied by the three twirling stars at the system's centre, or the break appeared when a planet formed within one of the rings. It was concluded that there's not enough turbulence in the rings for the stellar torque theory to work. Instead the models suggest that the presence of an enormous, Jupiter-size planet, or perhaps several planets, is the likelier explanation for the rings' strange shape and behaviour. If future observations of the system support that theory, GW Ori may be "the first evidence of a circumtriple planet carving a gap in real time," Jeremy Smallwood from the University of Nevada, Las Vegas, said.

Sadly, a hypothetical observer on this potential planet wouldn't actually be able to see all three suns rise and fall in the sky; the two stars at the centre of the system move in such a tight binary orbit that they would appear as one great star, with the third swooping around them. If a planet is confirmed, the mere existence of this world would prove that planets can form under a wider array of conditions than scientists previously realised. If three suns and a wobbling mishmash of dust rings aren't enough to thwart a fledgling planet, then who knows what is.



GW Orionis has three stars centred within three wobbly rings of dust. Astronomers think there could be a rare three-sun planet in the mix too

© Getty / ESO/A. Caicedo, Exeter/Kraus et al.

WISH LIST

The latest CODING TOY TECH

WOWWEE COJI

£49.99 / $31.99 WWW.AMAZON.CO.UK / WWW.WOWWEE.COM/COJI

Kids can program the WowWee COJI coding robot by using emojis. They can use a tablet or smartphone to load programs onto the robot, though some basic functions are available even without a mobile device. The emojis describe the robot's actions. For example, a sequence of directional symbols will send the robot moving in those directions, and adding the emoji for a musical instrument will make it play a small flourish when done. Kids can also add programming tools such as 'if-then' statements. The apps for the COJI coding robot include games that illustrate how to create specific and sequential instructions for the robot. This relatively simple toy is ideal for kids aged four to seven, and is sure to provide hours of fun for the junior programmer in your household.

LEGO BOOST CREATIVE TOOLBOX

£149.99 / $159.99

WWW.LEGO.COM

The Boost Creative Toolbox allows for five different programmable robots, or robot-like models, from a kit that includes bricks, a central-processing unit and sensors. The robot can be programmed from an iPad or Android tablet with the included app. The build projects are complex, but less so than LEGO's Mindstorms kits; kids can program using a block-based system that connects to the robots via Bluetooth. As usual with LEGO, the Boost components are compatible with other LEGO sets, so once a child has built, for example, Vernie the robot, they can customise it, maybe using superhero or Star Wars-themed sets, or something completely unique. This STEM toy might be on the expensive side, but the extra IQ points will be worth it.

THINKFUN CIRCUIT MAZE ELECTRIC CURRENT LOGIC GAME

£28.64 / $31.99 WWW.AMAZON.COM

With this game, older kids can build actual circuits using a 5x5 grid, on which the player draws a challenge card and then has to insert mechanical components to make a working circuit in order to turn on a light. The challenges have more than one 'right' answer, though the pieces have to be placed in the right order. This game can also be used without an internet connection – though it does require three AAA batteries – and it's an affordable option for developing those critical-thinking skills.

AILA SIT & PLAY

$199 (APPROX. £147) WWW.ANIMALISLAND.US

If you want to encourage critical-thinking skills from the get-go, consider the Animal Island Learning Adventure (AILA) Sit & Play virtual early preschool learning system, a hands-free, subscription-free virtual playground of educational content carefully curated by professional educators and industry innovators. The AILA Sit & Play uses a unique combination of hardware, software, cognitive AI and a robust preschool curriculum that comes in a colourful, toddler-friendly format. It's one of the best ways to introduce your preschooler to mathematics, problem-solving and collaborative thinking. This educational tablet isn't a coding toy per say, but the AILA Sit & Play will absolutely pave the way for the best coding toys found here as your toddler learns about basic colours, shapes, numbers and words.

SPHERO MINI

£39.99 / $49.99 WWW.AMAZON.CO.UK / WWW.SPHERO.COM

Available in 11 different colours, the Sphero Mini is an app-enabled robotic ball that packs lots of fun in a small package – about the size of a ping-pong ball. This capable little robot is equipped with a gyroscope, accelerometer and colourful LED lights; curious kids can control the Sphero Mini via smartphone in Joystick, Slingshot or Tilt mode. The accompanying app also lets them use the robot as a game controller for arcade-style games. In Blocks Drive mode your child can learn the basics of drag-and-drop coding commands, but more advanced learners can download the Sphero Edu app (compatible with iOS and Android) for more ways to program this educational bot, including JavaScript and Swift. Founded in 2010, Sphero is looking to change the world with its fleet of STEM-friendly educational robots, allowing children to learn, create, invent and explore the world around them like never before.

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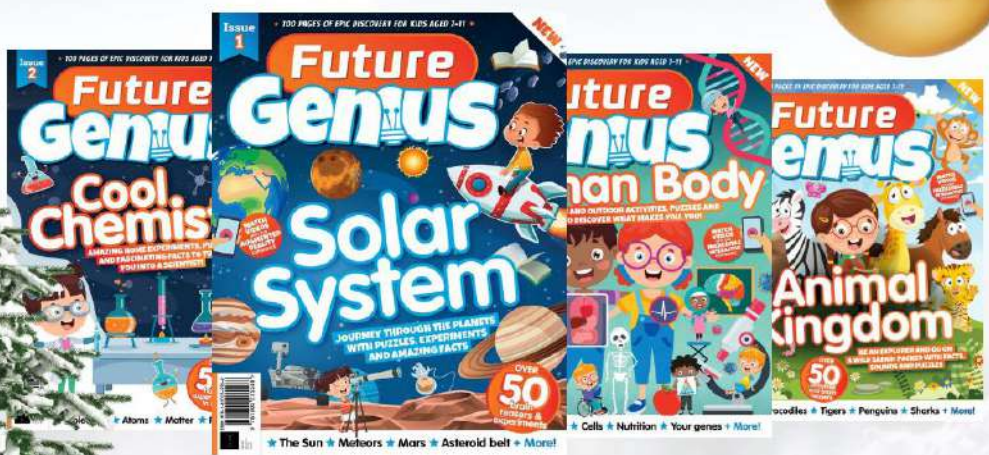

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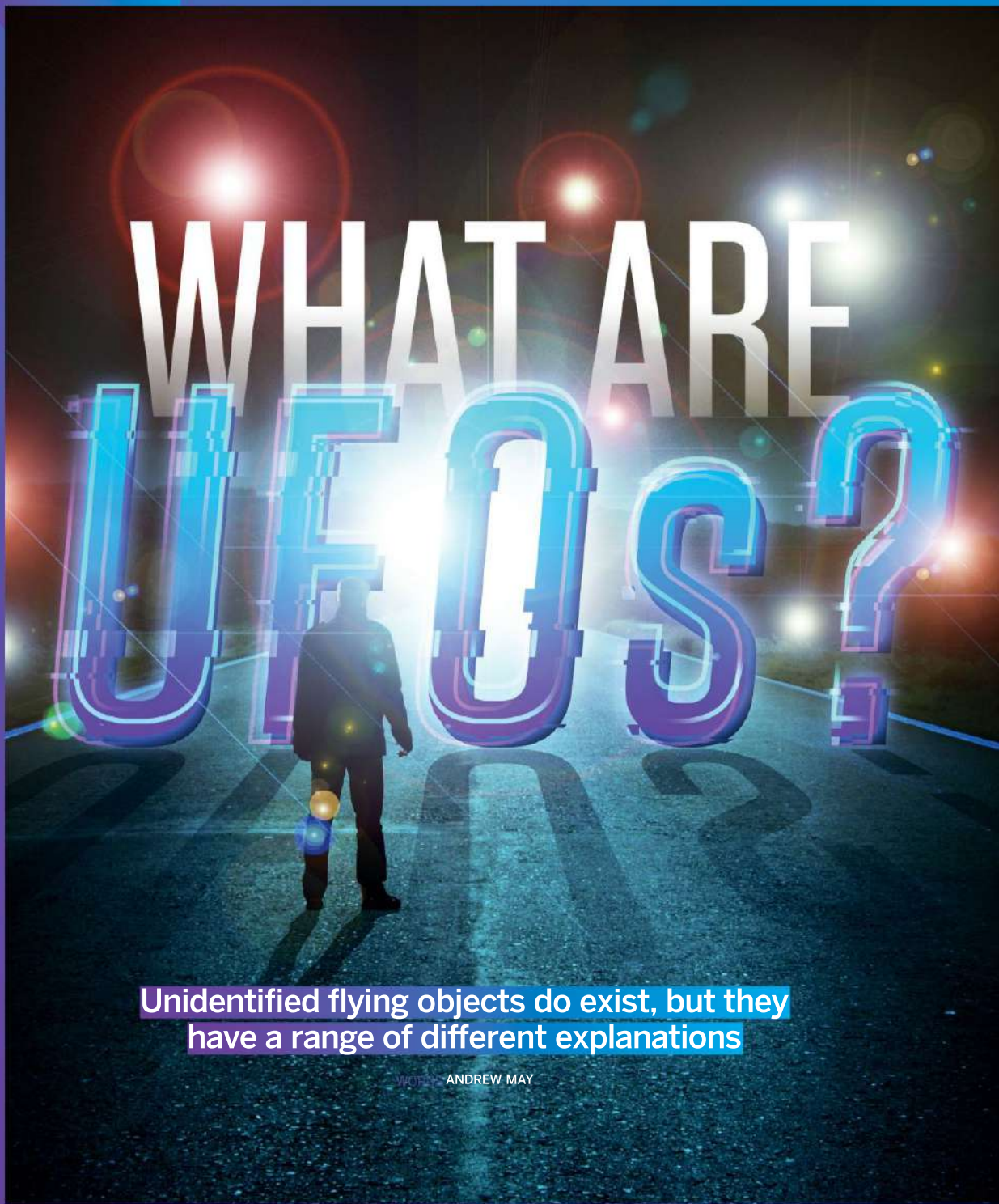


WHAT ARE UFOS?

Unidentified flying objects do exist, but they have a range of different explanations

WORDS ANDREW MAY

DID YOU KNOW? The term UFO was coined by Edward J. Ruppelt, an officer in the US Air Force, in the 1950s

There have been sightings of strange things in the sky since ancient times, but it was only in the middle of the 20th century they acquired the name 'unidentified flying object', or UFO. During the 1940s and 1950s, there was a huge surge in sightings around the world, often described as disc-shaped craft or 'flying saucers'. The timing of this first great UFO wave was significant, coming at a period of widespread public paranoia caused by the nuclear arms race. The most common theory in the early days was that UFOs were advanced military aircraft that had been developed in total secrecy.

Within a few years public perceptions changed, thanks in part to Hollywood. Suddenly UFOs were no longer assumed to originate on Earth, but from another planet. Since then, the situation has been complicated by other alleged evidence for extraterrestrial visitation, from rumours that governments are concealing information about their dealings with UFO occupants to apparent memories of alien abduction recalled under hypnosis. Although these cases have little or no direct connection to strange objects seen in the sky, the term UFO still tends to be applied to them. Last year, for example, a UK newspaper carried the headline 'UFO hunter spots alien lizard on Mars', even though no flying object was involved.

The fact is that the terminology has become hopelessly confused. To some people, particularly in official circles, 'unidentified flying object' means just that: an airborne object that hasn't been identified. To many ordinary people, however, UFO means 'alien spacecraft'. For this reason, the US military has started using the term UAP, for unidentified aerial phenomena, to avoid appearing to talk about extraterrestrials every time they say they've seen something they can't explain. And UAP has another advantage, because UFOs may not always be literal 'flying objects'. As you'll see, some may be mirages, unusual weather effects or even astronomical bodies. Therefore 'aerial phenomena' is a much more appropriate term in these cases.

UFO and UAP do have one letter in common, and that's U, for unidentified. But it's important not to read too much into this. It doesn't automatically mean that what's been spotted came from another planet, or defies the known laws of physics. In the case of a photograph or video, for example, the resolution simply may not be good enough to work out what it shows.

With a fleeting eyewitness report, even by a trained observer like a pilot or police officer, if they had no firm idea of the size or distance of the object, it might have been anything from a person's drone to an alien starship. And electronic systems such as radar are designed to pick up particular types of known objects, so anything falling outside the expected parameters is likely to be classed as 'unidentified'. A proportion of UFO reports still remain unexplained – but not necessarily extraterrestrial – even after careful investigation.

The majority of sightings can eventually be ascribed to known causes – anything from top-secret spy planes to obscure atmospheric phenomena. We'll take a look at some of these 'real-world UFOs' here, as well as questioning one of the people behind the public release of half a century's worth of Ministry of Defence (MoD) UFO files.

Above: Cloud phenomena are responsible for some sightings

Above inset: In common usage, UFO means alien spaceship, but there are many other explanations

© Getty

THE PENTAGON UFO VIDEOS

The idea that some UFO sightings might represent genuinely unknown phenomena was given a boost in 2020 when the Pentagon – the US defence headquarters – released three videos staff admitted couldn't be explained. The low-resolution, black-and-white videos show the instrument displays inside US Navy fighter jets, recorded during encounters that baffled flight crews at the time. The first video, entitled 'FLIR' – for Forward-Looking Infrared, a reference to the equipment used to capture the video – dates from 2004, while two others, called 'GIMBAL' and 'GOFAST', come from 2015. The latter are more dramatic, with the 'UFO' apparently in rapid motion and the crew's surprised reactions audible in the background.

Despite the Pentagon's inability to explain the videos, numerous theories have been put forward by the public, ranging from optical illusions and instrument malfunctions to unusual atmospheric phenomena and – of course – alien spacecraft.

A still from a US Navy video, dating from 2019, appears to show a triangular UFO

The FLIR video, taken by US Navy pilots off the coast of San Diego

SCAN TO WATCH

The GIMBAL video, showing an encounter off the US east coast

This video, called GOFAST, is from the same encounter as GIMBAL

"The Pentagon released three videos staff admitted couldn't be explained"

The bright planet Venus is frequently mistaken for a UFO

Did you know?
Some UFO sightings have been exposed as hoaxes

PARALLAX ILLUSION

If you walk past a stationary object, it appears to move relative to the background. This effect is called parallax, and our brains are so used to it we don't notice when everyday objects are involved. But if there aren't any familiar visual cues, it really can seem as though a stationary object is in motion. Some believe this is what we're seeing in the GOFAST video. The idea is that the object is nowhere near the sea's surface, but much closer to the aircraft taking the video. Even if the object was almost stationary, it would appear to whiz over the sea at the same speed as the aircraft itself.

How parallax makes stationary objects appear to move against a distant background

SCAN TO WATCH

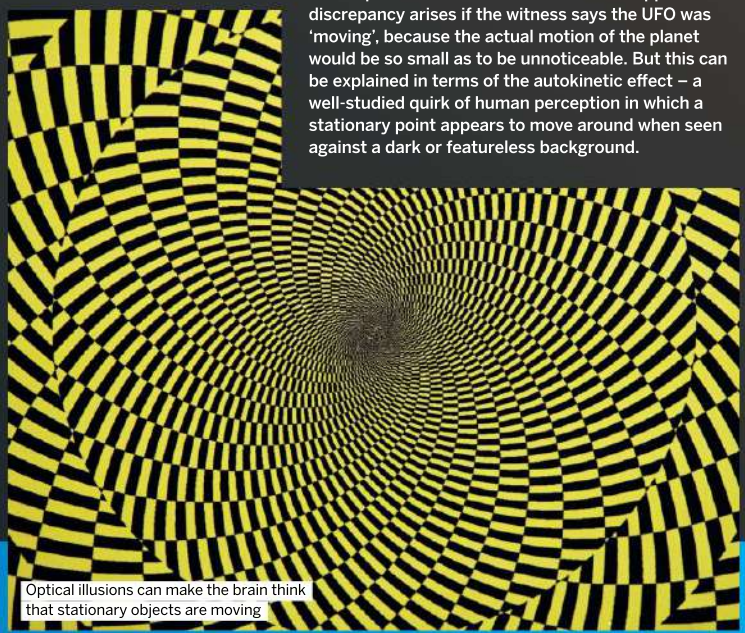
GRAVITY-DEFYING MIRAGES

In certain weather, particularly over the sea or flat terrain, it's possible to see distant objects 'hovering' in midair. Sometimes it's obvious that what you're seeing is a building or a ship, but other times it can look like a UFO. But this has a perfectly rational explanation in terms of optics. It all comes down to the fact that light doesn't always travel in straight lines. In medieval times people thought mirages were created by supernatural means, dubbing them Fata Morgana after a mythical sorceress.

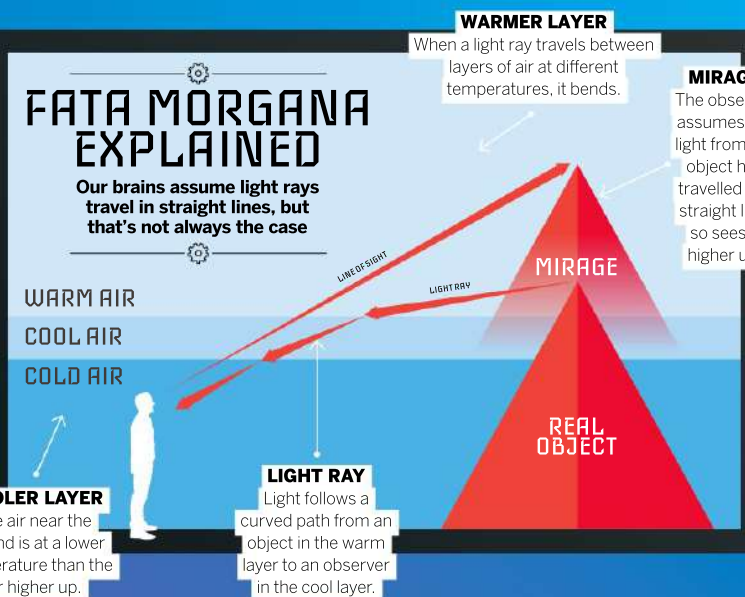
This looks like a hovering spaceship, but it's a Fata Morgana mirage

THE AUTOKINETIC EFFECT

Over the years, a large number of UFO sightings have been found to be misidentifications of the planet Venus. In these cases, the location of the object in the sky, as described by the witness, exactly matched the known position of Venus at that time. An apparent discrepancy arises if the witness says the UFO was 'moving', because the actual motion of the planet would be so small as to be unnoticeable. But this can be explained in terms of the autokinetic effect – a well-studied quirk of human perception in which a stationary point appears to move around when seen against a dark or featureless background.



Optical illusions can make the brain think that stationary objects are moving


FATA MORGANA EXPLAINED
Our brains assume light rays travel in straight lines, but that's not always the case
WARMER LAYER
When a light ray travels between layers of air at different temperatures, it bends.
MIRAGE
The observer assumes the light from the object has travelled in a straight line, so sees it higher up.
LINE OF SIGHT
LIGHT RAY
MIRAGE
WARM AIR
COOL AIR
COLD AIR
REAL OBJECT
COOLER LAYER
The air near the ground is at a lower temperature than the air higher up.
LIGHT RAY
Light follows a curved path from an object in the warm layer to an observer in the cool layer.

© Alamy / Getty / European Southern Observatory / Wiki: NuclearDuckie

TOP-SECRET AIRCRAFT

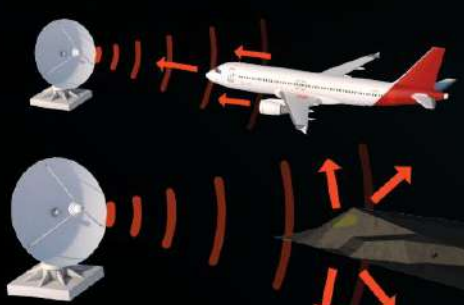
The B-2 stealth bomber looks like alien tech from certain angles

Many UFOs aren't 'flying objects' at all, but planets, mirages or unusual atmospheric phenomena. On the other hand, some are exactly what they appear to be – ultra-futuristic flying machines – except they originate here on Earth, not in outer space. The CIA estimates that more than half of all UFOs reported in the US during the 1950s and 1960s were the nation's own spy planes. The very existence of these aircraft was a carefully guarded state secret, and the military much preferred the public to speculate about aliens than to uncover the true facts. A new twist was added in the 1970s with the advent of stealth aircraft such as the F-117, and later the B-2. During their development and initial deployment, these were every bit as secret as the earlier spy planes, while the requirement to disrupt incoming radar signals made them the most oddly shaped aircraft in the sky.

Did you know?
During WWII, allied pilots referred to UFOs as foo fighters

NORTHROP GRUMMAN B-2

The B-2's weird appearance doesn't mean it's from another planet... it's all about stealth



WING ENGINES
The two engines are mounted inside the wings so they don't add radar reflections of their own.

RADAR SCATTERING
Rather than reflecting radar waves back the way they came, the B-2 is shaped so they bounce off at an angle.

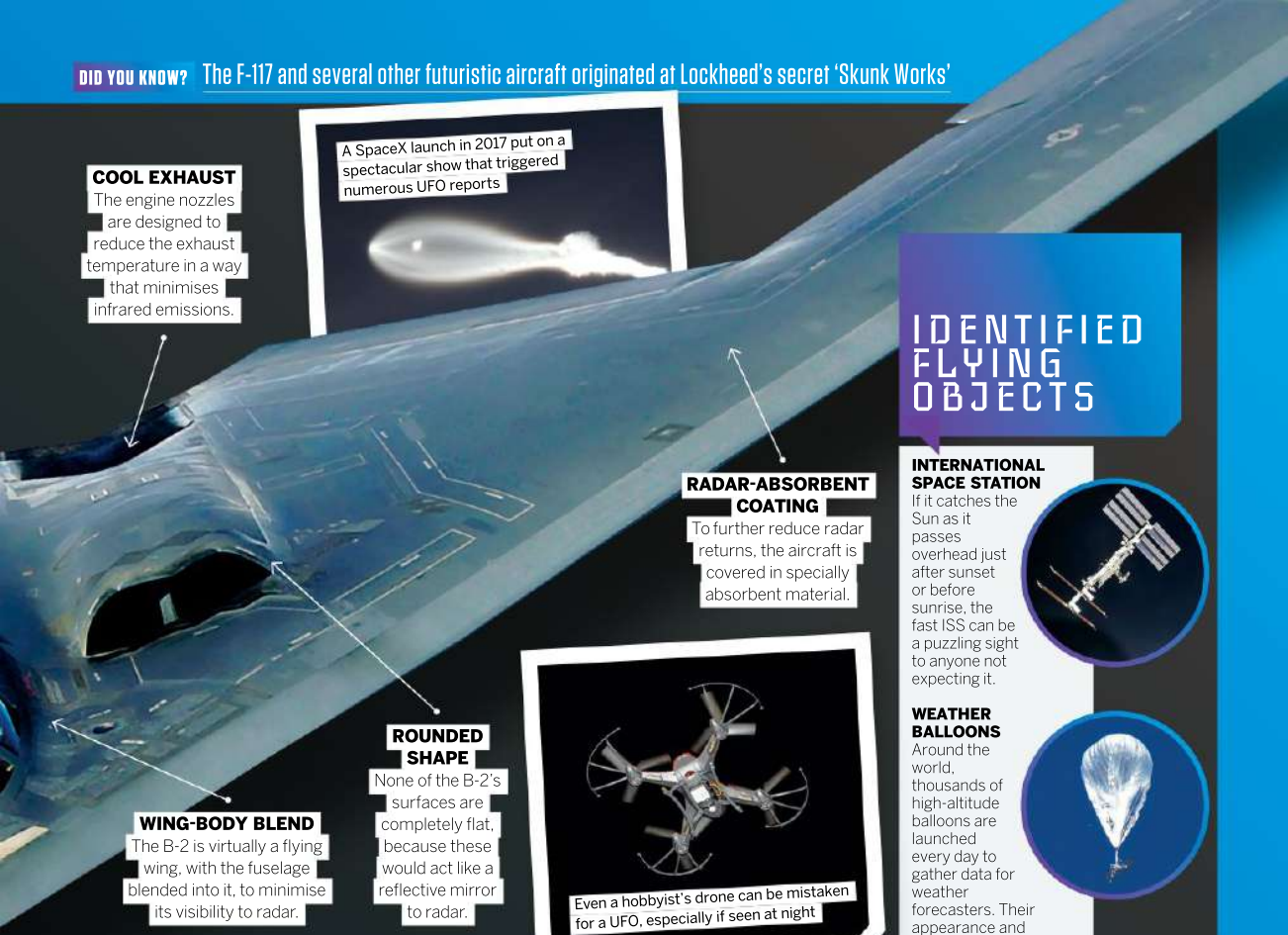
Seen nose-on, the Lockheed Martin F-117 looks like a classic UFO

LOCKHEED F-117 NIGHTHAWK 1981

Designed primarily for stealth, the F-117 was developed – and initially operated – in total secrecy. Its existence was only revealed to the public in 1988, five years after it entered service with the US Air Force. The combination of secrecy and a strikingly unconventional appearance were guaranteed to produce UFO reports.

AR zone SCAN HERE

DID YOU KNOW? The F-117 and several other futuristic aircraft originated at Lockheed's secret 'Skunk Works'



A SpaceX launch in 2017 put on a spectacular show that triggered numerous UFO reports

COOL EXHAUST
The engine nozzles are designed to reduce the exhaust temperature in a way that minimises infrared emissions.

RADAR-ABSORBENT COATING
To further reduce radar returns, the aircraft is covered in specially absorbent material.

ROUNDED SHAPE
None of the B-2's surfaces are completely flat, because these would act like a reflective mirror to radar.

WING-BODY BLEND
The B-2 is virtually a flying wing, with the fuselage blended into it, to minimise its visibility to radar.

Even a hobbyist's drone can be mistaken for a UFO, especially if seen at night

Only one V-173 was built

VOUGHT V-173 1942 'FLYING PANCAKE'

This weird experimental aircraft was built for the US Navy at the start of World War II. A classic 'flying saucer' shape with an almost-circular disc-shaped wing, it underwent almost 200 test flights in the Connecticut area, prompting numerous UFO reports from locals.

The Ho 229 was the first flying wing powered by jet engines

HORTEN HO 229 FLYING WING 1944

An aircraft way ahead of its time, this jet-powered flying wing superficially resembles the Northrop Grumman B-2 built half a century later. The Ho 229 was built by Nazi Germany for a last-ditch offensive against the Allies, but the war ended before it could enter service.

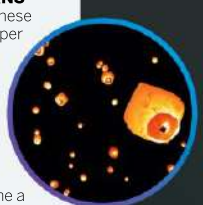
IDENTIFIED FLYING OBJECTS

INTERNATIONAL SPACE STATION
If it catches the Sun as it passes overhead just after sunset or before sunrise, the fast ISS can be a puzzling sight to anyone not expecting it.

WEATHER BALLOONS
Around the world, thousands of high-altitude balloons are launched every day to gather data for weather forecasters. Their appearance and behaviour can seem mysterious to anyone unfamiliar with them.

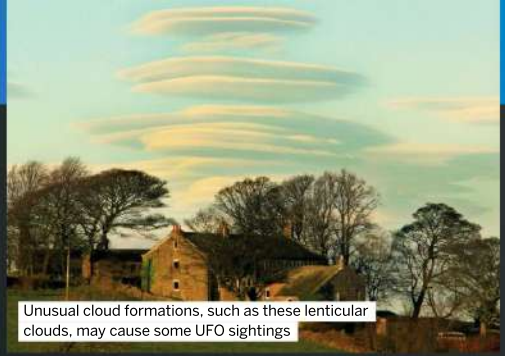
SATELLITE LAUNCHES
With the new generation of broadband satellites, such as Starlink, being launched in batches, the tightly clustered satellites seen just after launch are often mistaken for UFOs.

SKY LANTERNS
The craze for these celebratory paper balloons, illuminated by candles and launched en masse, began in China, but is now worldwide. They've become a common cause of UFO sightings.



© Alamy / Getty / NASA

ATMOSPHERIC PHENOMENA



Unusual cloud formations, such as these lenticular clouds, may cause some UFO sightings

Earth's atmosphere is a dynamic, constantly changing environment, and some of the more spectacular effects that occur in it can look like UFOs to the uninitiated. These include the unusual weather phenomena described in the graphics here, such as ball lightning, fallstreak holes and lenticular clouds. The latter in particular are a perennial cause of UFO sightings due to their highly symmetrical and structured appearance.

In a single month in 2015, the *Houston Chronicle* reported dozens of these false alarms, quoting one excited Twitter user as saying: "The sky over Texas appears to be filled with UFOs!"

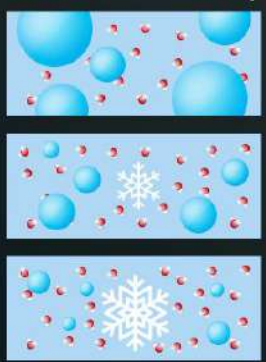
Meteors are another natural phenomenon that can be mistaken for UFOs. These really do come from space, although they're just dust or small pieces of rock rather than alien spacecraft. They produce a glowing trail as they enter the atmosphere, and larger ones may explode on the way down – sometimes audibly – creating a spectacular light show that is almost guaranteed to generate UFO reports. Similar effects can be produced by human-made space junk, such as derelict satellites, as they re-enter the atmosphere.

Did you know?
A hundred tonnes worth of meteors hit Earth every day

"There are almost as many explanations as there are sightings"

FALLSTREAK CLOUDS

This odd phenomenon causes a circular hole to appear in an otherwise normal cloud layer



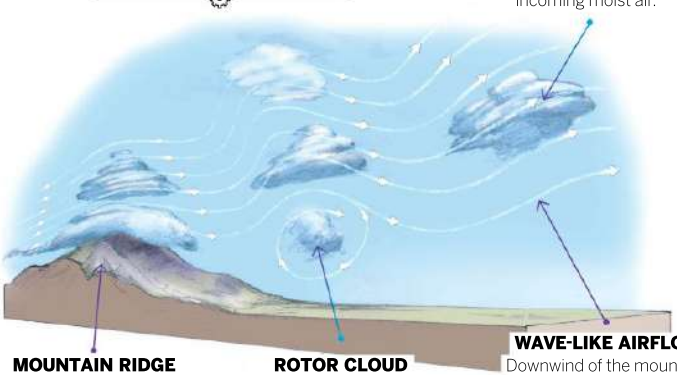
SUPERCOOLED CLOUD
Temperatures are below freezing, but the water droplets remain liquid due to a lack of ice nucleation particles.

CLOUD FREEZES
When ice crystals start to form, they set off a domino effect in which more and more water freezes.

A HOLE IS CREATED
When the ice crystals are big enough, they begin to fall as snow, leaving a big hole in the cloud.

LENTICULAR CLOUDS

These strikingly dramatic clouds can often look like giant flying saucers



LENTICULAR CLOUDS
The characteristic saucer-shaped clouds form at the peak of the standing wave, constantly replenished by incoming moist air.

MOUNTAIN RIDGE
A current of moist air is forced up and over a high ridge.

ROTOR CLOUD
Sometimes a rotating cylindrical cloud can form underneath the lenticular cloud.

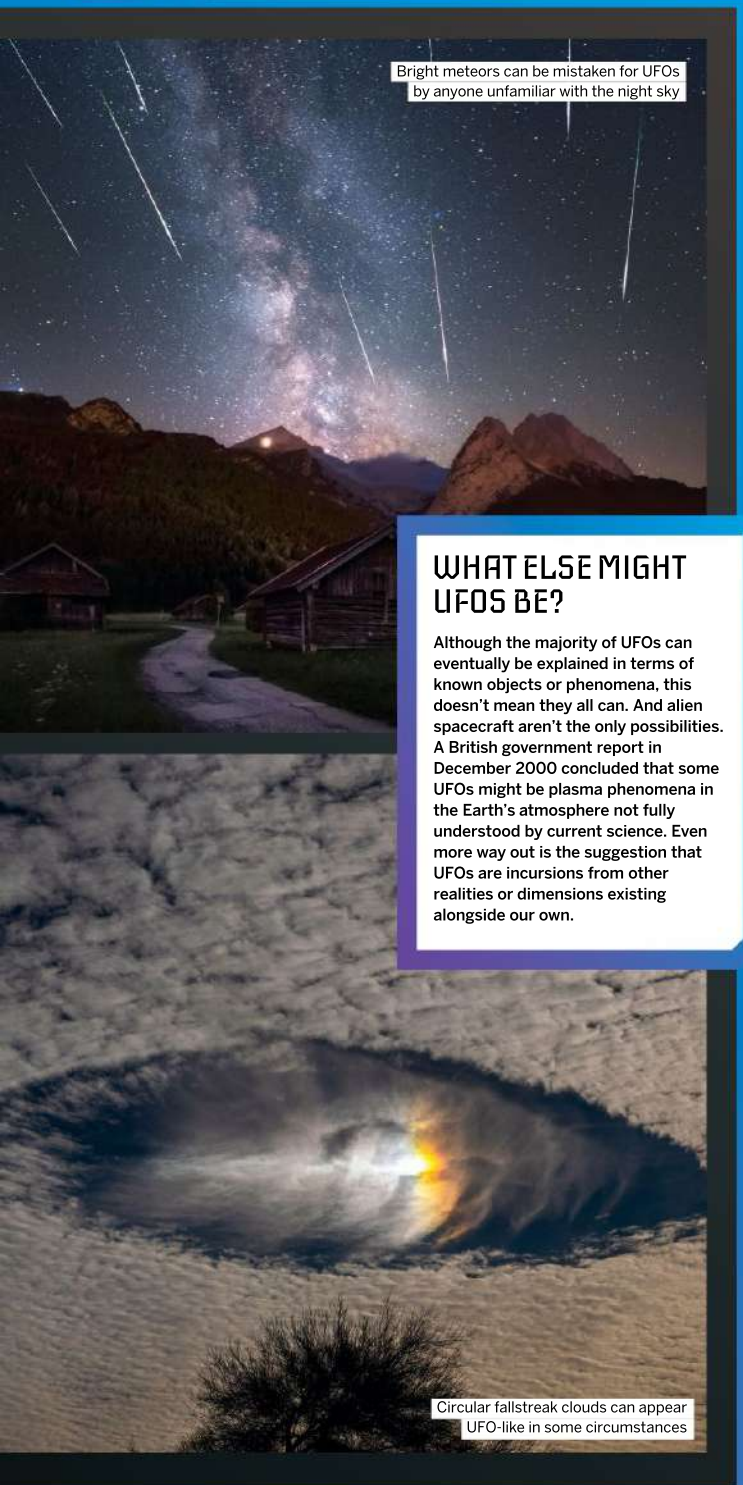
WAVE-LIKE AIRFLOW
Downwind of the mountain, the airflow forms a 'standing wave' pattern of crests and troughs.

BALL LIGHTNING

Reports of ball lightning go back centuries, yet it remains a mystery to science. Although it's associated with thunderstorms, it differs from a normal lightning flash in lasting several seconds. Also, as the name suggests, it takes the form of a small sphere. Despite the consistency of eyewitness accounts, unambiguous photographs are scarce, and numerous scientific explanations have been put forward. Some of these have been shown to produce effects similar to ball lightning under laboratory conditions, but it's not yet clear which theory – if any – is correct.

Ball lightning seen from a distance might be mistaken for a UFO

DID YOU KNOW? The MoD's investigation of UFOs began in 1952 at the request of Winston Churchill, the UK's prime minister at the time



Bright meteors can be mistaken for UFOs by anyone unfamiliar with the night sky

Circular fallstreak clouds can appear UFO-like in some circumstances

WHAT ELSE MIGHT UFOS BE?

Although the majority of UFOs can eventually be explained in terms of known objects or phenomena, this doesn't mean they all can. And alien spacecraft aren't the only possibilities. A British government report in December 2000 concluded that some UFOs might be plasma phenomena in the Earth's atmosphere not fully understood by current science. Even more way out is the suggestion that UFOs are incursions from other realities or dimensions existing alongside our own.

Dr David Clarke is an associate professor at Sheffield Hallam University

THE MINISTRY OF DEFENCE AND UFOS

Since 2008, David Clarke has worked with the National Archives on releasing the MoD's UFO files

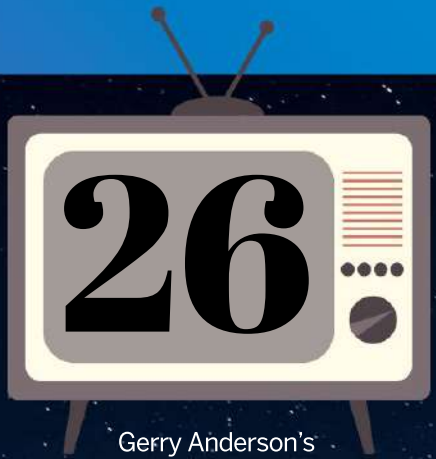
Could you give us a quick idea of what the files contain?
There are two sets of files. The first are paper ones transferred to the National Archives under the old 30-year rule. These cover roughly 1950 to 1984, but are very patchy because many earlier records were destroyed. The second set are from 1984 until 2009, when the MoD closed its public UFO desk. Both sets consist of UFO policy, sighting reports and public and parliamentary correspondence.

Looking at the sightings reported by the public, do some of them have obvious explanations?
The vast majority of the 12,000 sightings logged by the MoD have down-to-earth explanations, but some remain unexplained. The truth is they never had resources to do more than a few basic checks on reports, and very few were investigated properly. There are almost as many explanations as there are sightings – everything from paper lanterns to bright planets and space debris. The MoD received 750 reports in 1978, one of the largest totals – this was the same year Spielberg's film *Close Encounters of the Third Kind* was released!

Can you give a couple of examples of sightings that are harder to explain?
One of the most puzzling is the Calvine incident from 1990. Two men saw a large diamond-shaped object hovering above moorland in Scotland and took six photographs. They show the UFO being shadowed by what appears to be an RAF Harrier. But the image in the files is a poor-quality copy. The case was investigated by MoD intelligence, but there's little in the files that reveals the results. The most famous incident in the files is the Rendlesham Forest encounter in Suffolk in 1980. Both cases provide examples of the limitations of these records in that sensitive information has been removed and in some cases destroyed.

© Alamy / Getty / David Clarke

UFOs BY NUMBERS



26

Gerry Anderson's classic TV series *UFO* ran for over two dozen episodes

3

Categories of UFO 'close encounter' – the third kind involves occupants

The radar cross section of an F-117 is less than that of some birds

30CM²

13,500

There were thousands of witnesses to a huge triangular UFO in Belgium in 1990

7,267

Worldwide UFO sightings in 2020

MOST ASTROBIOLOGISTS BELIEVE ALIENS EXIST, BUT DON'T VISIT EARTH IN SPACESHIPS

35,000

Thousands read Britain's now-defunct *UFO Magazine* at its height

A PERSON WHO STUDIES UFOS IS CALLED A UFOLOGIST

28 MONTHS

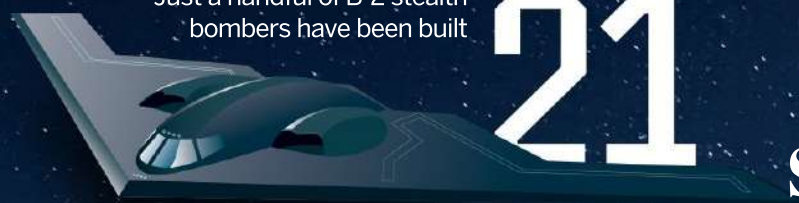
It was over two years before the Pentagon videos leaked to the media were officially released

FATA MORGANA MIRAGES GAVE RISE TO THE 'FLYING DUTCHMAN' LEGEND

35%
Over a third of Americans believe extraterrestrials are visiting Earth

Just a handful of B-2 stealth bombers have been built

21



3,500 METRES
Lenticular clouds typically form at the same altitude as a tall mountain's peak

$22 MILLION
A small fraction of budget was spent by the Pentagon on UFO research between 2007 and 2012

THE LATE PRINCE PHILIP HAD A LIFELONG INTEREST IN UFOS

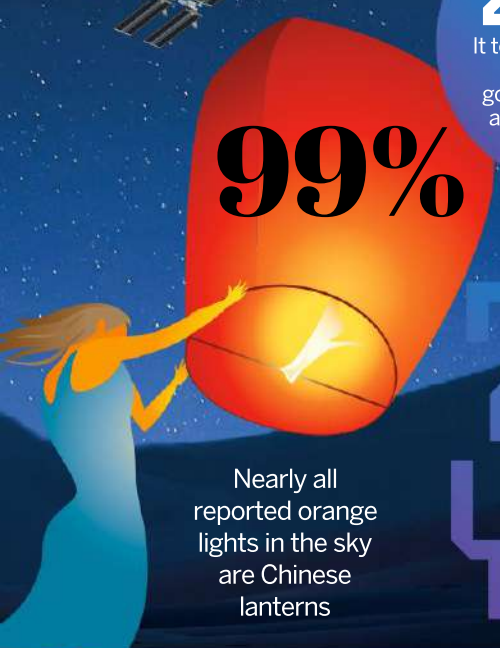
THIRD
The brightest celestial object after the Sun and Moon is the ISS

2013
It took nearly 60 years before the US government publicly acknowledged that Area 51 existed

7%
A small portion of UFO sightings remain unexplained after investigation

16
There are over a dozen different scientific explanations of ball lightning listed on Wikipedia

99%
Nearly all reported orange lights in the sky are Chinese lanterns



76,500 YEARS
The time it would take for our fastest spacecraft to reach another star

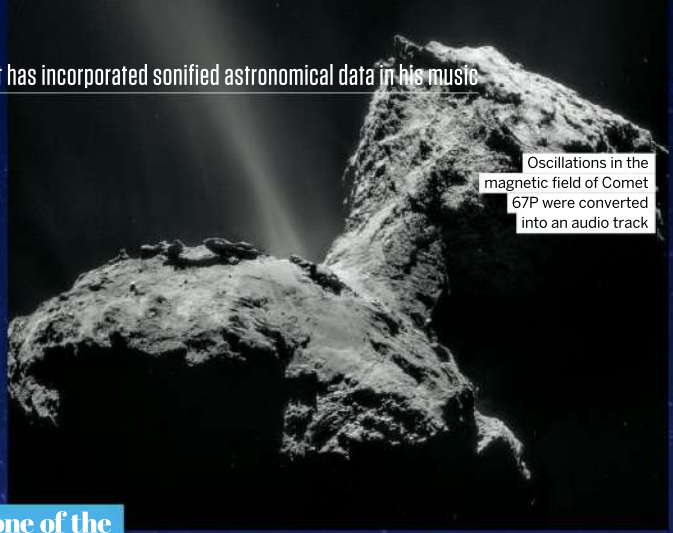
© Getty

WHAT DO PLANETS SOUND LIKE?

WORDS ANDREW MAY

From Martian winds to Saturn's aurorae, how sounds add to our understanding of the planets

DID YOU KNOW? Former Grateful Dead drummer Mickey Hart has incorporated sonified astronomical data in his music



Oscillations in the magnetic field of Comet 67P were converted into an audio track

This year, for the very first time, people on Earth have been able to hear the sounds of Mars thanks to two microphones installed on board NASA's Perseverance rover. The audio clips captured so far range from a gust of Martian wind to the snapping sound of the rover's laser hitting a rock. These sounds are subtly different from what you'd hear on Earth, being quieter and more muffled due to the lower density and different composition of the Martian atmosphere. Even so, anyone expecting other planets to sound truly 'alien' might be disappointed by just how ordinary Perseverance's recordings sound.

But there are other possibilities. The sounds we hear are wavelike vibrations of air molecules occurring within the range of frequencies that our ears are sensitive to. However, it's possible to process any other kind of wave or oscillation electronically, scaling it to audible frequencies and then converting it into a sound wave. This can be done with virtually any type of astronomical data, often with distinctly spooky results. Quite apart from its entertainment value, the process of turning non-acoustic data into audible sounds – called sonification – can have benefits for astronomers involved in analysing the data.

> "This was one of the first pure audio clips to go viral"

One of the best-known examples came from the European Space Agency's (ESA) Rosetta mission to comet 67P/Churyumov-Gerasimenko. This particular sonification, released during the spacecraft's encounter with 67P in November 2014, was based on low-frequency oscillations in the comet's magnetic field, which were then scaled up by a factor of 10,000 to make them audible. Called 'the singing comet' and heard over 5 million times, this was one of the first pure audio clips to go viral after it was posted on SoundCloud.

Another promising source of outer space 'sound' is radio astronomy. One of the first uses of radio here on Earth was for sound broadcasting, and just as an audio signal can be carried by a radio wave, so radio telescope data can be transformed into audible sounds.

In this context, one of the pioneers of 'acoustic astronomy' – initially as an aid to data analysis, and more recently as a form of science outreach – is Fiorella Terenzi. She began converting radio waves from distant galaxies into audio form while she was still a student in 1987. Now a professor at Florida International University, Terenzi has applied similar techniques to other astronomical data, including radio emissions from the gas giant planets Jupiter and Saturn and Earth's own magnetosphere.

While ground-based radio telescopes listen in on signals originating from vast distances away, sensors fitted to interplanetary spacecraft can 'hear' radio waves – and other types of signals – in situ. Here we take a brief look at some of the otherworldly sounds that have been recorded.

SCAN TO LISTEN

Saturn's aurorae are the source of intense radio emissions, which have been converted into sounds

SOUNDS OF JUPITER AND SATURN

When NASA's Juno spacecraft crossed the boundary between interplanetary space and Jupiter's magnetosphere in 2016, there was an abrupt change in the electric field measurements it recorded. In a YouTube video from NASA's Jet Propulsion Laboratory, these measurements were converted into sound waves, bringing out the dramatic nature of the change much more vividly than a conventional graphical representation.

More than a decade earlier, NASA released another striking audio clip, in this case captured by Cassini. This eerie recording, displaying an amazing range of variations in both frequency and time, is derived from Saturn's radio emissions. These are closely related to Saturn's aurorae, which like Earth's occur around the poles of the planet.

© Getty / ESA / Hubble / Alamy

Perseverance's microphones picked up the sound of the Ingenuity helicopter in flight

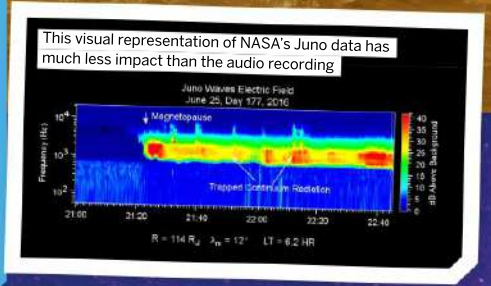
Terenzi was one of the original pioneers of 'acoustic astronomy'

SCAN TO LISTEN

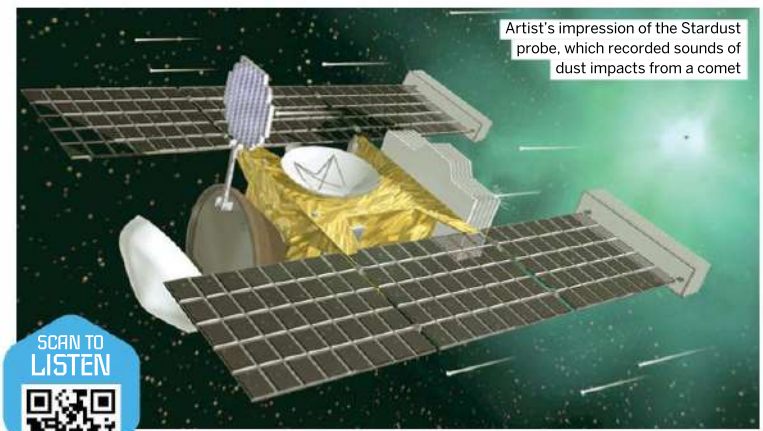
LANDERS WITH MICROPHONES

When NASA's Perseverance rover picked up the sounds of Mars in February 2021, it was the first to do so – but only just. Soon after, China released audio recordings made by its own Mars rover, Zhurong, part of the Tianwen-1 mission. So now we have a good idea of what the Red Planet sounds like – but what about other places that have atmospheres thick enough to carry sound waves?

The Soviet Union's Venera 13, which landed on Venus in March 1982, was the first spacecraft to record sounds on another planet. These include the Venusian wind and the sound of the probe itself hitting the ground. Years later, the European Space Agency's Huygens lander carried a microphone on its descent through the atmosphere of Saturn's moon Titan.



This visual representation of NASA's Juno data has much less impact than the audio recording



Artist's impression of the Stardust probe, which recorded sounds of dust impacts from a comet

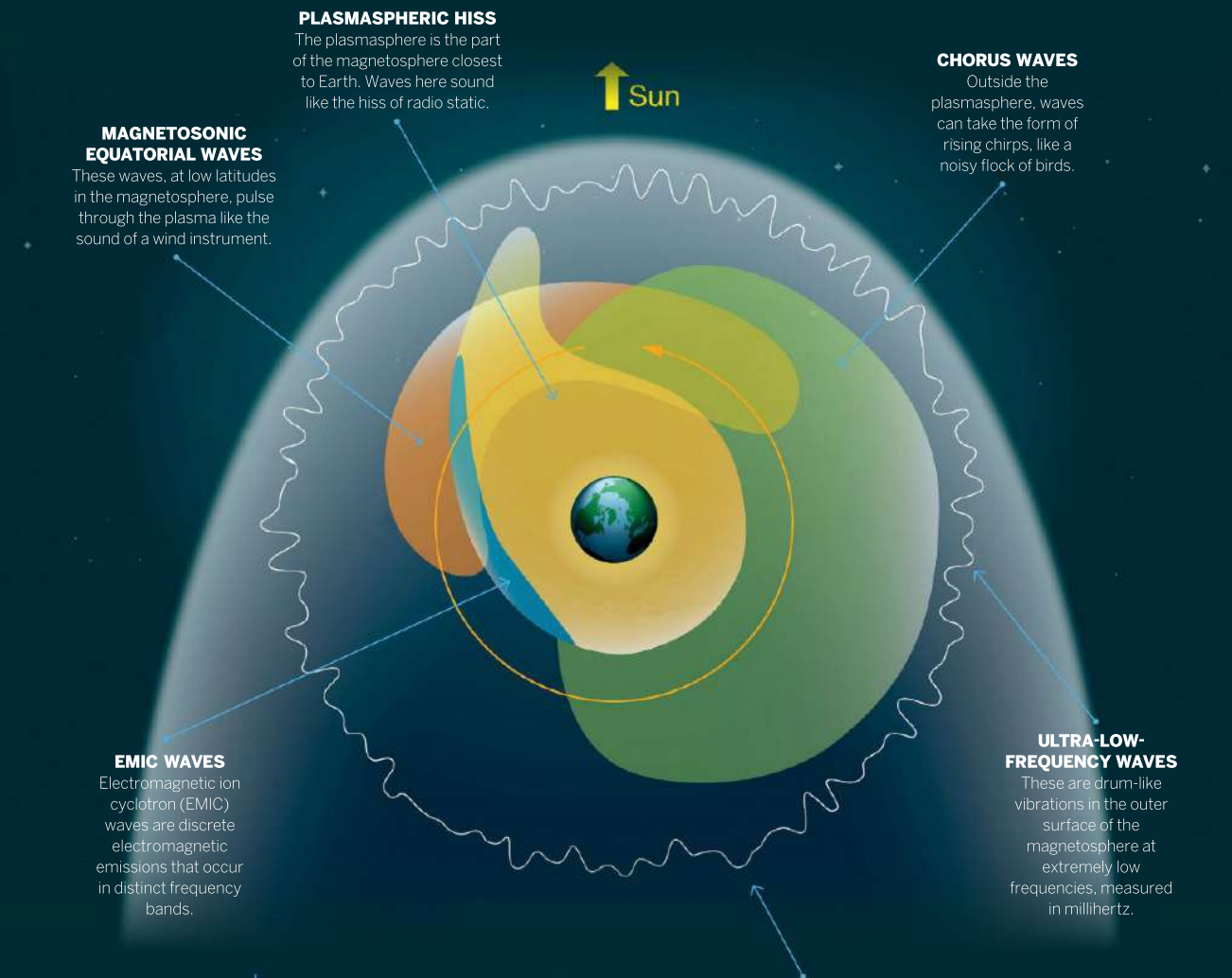
SCAN TO LISTEN

SOUNDS FROM A COMET ENCOUNTER

The electromagnetic sounds recorded by Rosetta on its cometary encounter required considerable processing to make them audible to human ears. But when an earlier probe, NASA's Stardust, flew past the comet Tempel 1 in 2011, it 'heard' something much closer to real sounds. While sound waves can't travel through space, dust grains and larger debris breaking off the comet could be heard when they hit the probe's protective shield. Around 5,000 impacts were detected over an 11-minute period as the spacecraft was pelted by fragments of dust and ice.

EARTH'S MUSICAL MAGNETOSPHERE

The tenuous plasma around Earth is filled with a cacophony of sound-like vibrations



PLASMASPHERIC HISS
The plasmasphere is the part of the magnetosphere closest to Earth. Waves here sound like the hiss of radio static.

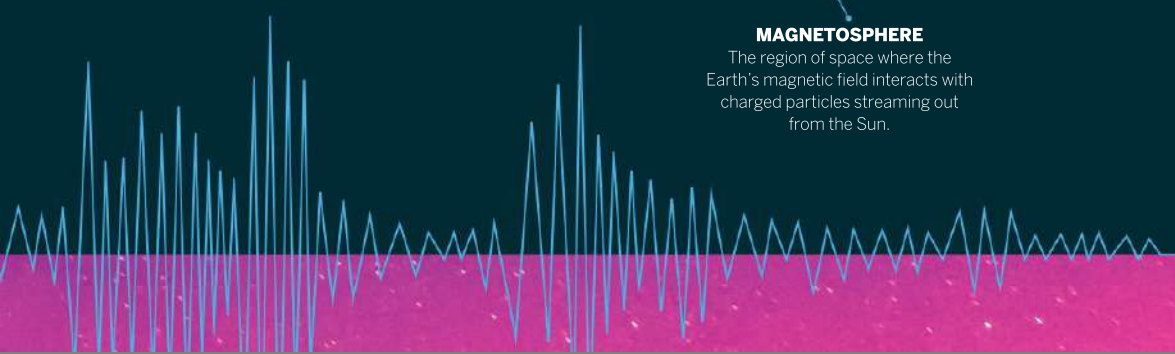
CHORUS WAVES
Outside the plasmasphere, waves can take the form of rising chirps, like a noisy flock of birds.

MAGNETOSONIC EQUATORIAL WAVES
These waves, at low latitudes in the magnetosphere, pulse through the plasma like the sound of a wind instrument.

EMIC WAVES
Electromagnetic ion cyclotron (EMIC) waves are discrete electromagnetic emissions that occur in distinct frequency bands.

ULTRA-LOW-FREQUENCY WAVES
These are drum-like vibrations in the outer surface of the magnetosphere at extremely low frequencies, measured in millihertz.

MAGNETOSPHERE
The region of space where the Earth's magnetic field interacts with charged particles streaming out from the Sun.



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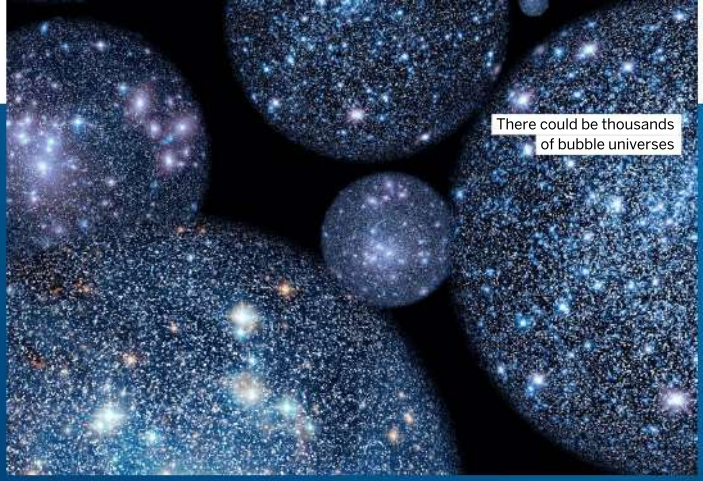


There could be thousands of bubble universes

WHAT IS THE MULTIVERSE?

Could the universe we know just be one of infinite universes?

WORDS **PAUL SUTTER**

Multiverse theory suggests that our universe, with all its hundreds of billions of galaxies and almost countless stars, spanning tens of billions of light years, may not be the only one. Instead there may be an entirely different universe, distantly separated from ours – and possibly countless others. There may be an infinity of universes, all with their own laws of physics, their own collections of stars and galaxies – if stars and galaxies can exist in those universes – and maybe even their own intelligent civilisations.

It could be that our universe is just one member of a much grander, much larger multitude of universes: a multiverse. Perhaps the most mind-bending implication of the multiverse is the existence of doppelgängers. If there really is an infinity of universes but a finite number of ways to arrange particles in any individual universe, then the same patterns are bound to be repeated eventually. That would mean that at some incredible – but finite – distance, there could be an exact copy of you reading an exact copy of this article. And because there would be an infinite number of universes, there would be an infinite number of these exact scenarios all happening simultaneously.

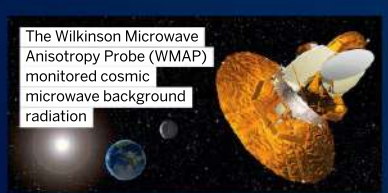
Did you know?
There would be no way to travel to another universe

MANY UNIVERSES

According to the theory, our universe is not alone

CLOSED UNIVERSE
Some universes expand so slowly that they fall back on themselves, resulting in self-destruction.

"There may be an entirely different universe, distantly separated from ours"



The Wilkinson Microwave Anisotropy Probe (WMAP) monitored cosmic microwave background radiation

PHYSICAL EVIDENCE

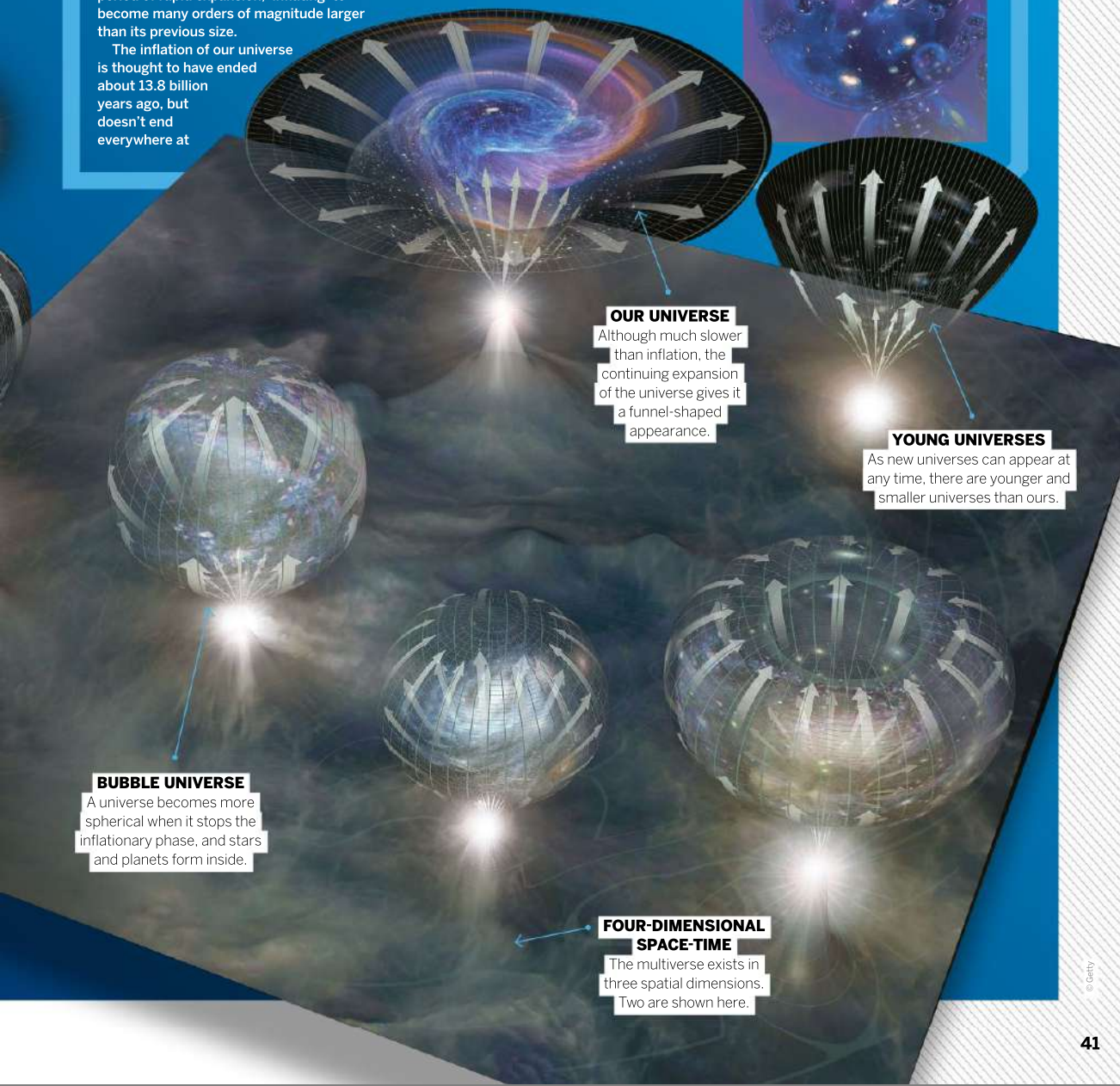
Many scientists have tried to find more physical, hard evidence for the multiverse's existence. For example, if a neighbouring universe happened to be close to ours long ago, it may have collided with our universe, creating a detectable imprint. That imprint could be in the form of distortions in the cosmic microwave background – the light left over from when the universe was a million times smaller than it is today – or in strange galaxy properties in the direction of the collision. But so far all the searches have come up empty, so the multiverse remains hypothetical.

THEORETICAL EVIDENCE

The concept of the multiverse arises in a few areas of physics – and philosophy – but the most prominent example comes from something called inflation theory. Inflation theory describes a hypothetical event that occurred when our universe was very young – less than a second old. In an incredibly brief amount of time, the universe underwent a period of rapid expansion, 'inflating' to become many orders of magnitude larger than its previous size.

The inflation of our universe is thought to have ended about 13.8 billion years ago, but doesn't end everywhere at the same time. While inflation ended in our universe, there may have been other, much more distant regions where inflation continued – and continues even today. Individual universes can likely 'pinch off' from larger inflating, expanding universes, creating an infinite sea of eternal inflation filled with numerous individual universes.

This concept shows individual universes 'pinching off' other expanding universes



OUR UNIVERSE
Although much slower than inflation, the continuing expansion of the universe gives it a funnel-shaped appearance.

YOUNG UNIVERSES
As new universes can appear at any time, there are younger and smaller universes than ours.

BUBBLE UNIVERSE
A universe becomes more spherical when it stops the inflationary phase, and stars and planets form inside.

FOUR-DIMENSIONAL SPACE-TIME
The multiverse exists in three spatial dimensions. Two are shown here.

© Getty

NASA ON MARS

How Mars missions of the past and present have greatly shaped our knowledge of the Red Planet

WORDS **AILSA HARVEY**

Mars conjures up images of a dry, dusty and desolate planet. But if you examine the minerals beneath its surface and the shape of every mound and crevice, it becomes apparent its past holds a different story. Craters once contained bodies of water, and its abundant liquid carved grooves and valleys. How do we know all of this about a planet millions of miles away from our own, and one which humans have never set foot on? Observations and findings have been achieved using machines.

Scientists and engineers on Earth can control and monitor these vehicles after they've completed their long journey to Mars. NASA's Deep Space Network (DSN) is an array of giant terrestrial radio antennae and satellites in orbit around Mars that creates communication links between the operators and their experiments on the Martian surface. The data the DSN receives, such as images from rovers on the ground, is transferred over radio waves. A rover will first send the data to one of NASA's Mars orbiters, which then relays the information back to Earth.

As we know it today, the thin, carbon dioxide-rich atmosphere that surrounds Mars makes it inhospitable to life. This has inspired many of the questions that NASA's missions aim to answer, such as what caused Mars' climate to change. Other mission objectives focus on present Mars conditions and what this means for the future of human exploration. Can scientists find evidence of past life on Mars? And what would we need from new technology that could aid human exploration there?

Did you know?
Mars' atmosphere is 100 times thinner than Earth's

EXTRATERRESTRIAL VEHICLES

Here are some of the NASA missions that have explored the Red Planet

MARS GLOBAL SURVEYOR
7 November 1996 to 2 November 2006
This space probe sent more than 240,000 images of Mars to Earth. The Mars Global Surveyor analysed the terrain and atmosphere. Its main findings include evidence of liquid water near the surface and the outer boundary of Mars' magnetic field.

MARINER 9
30 May 1971 to 27 October 1972
The first spacecraft to orbit another planet, it mapped 85 per cent of the planet's surface and took more than 7,000 pictures.

PHOENIX LANDER
4 August 2007 to 24 May 2010
This lander used its robotic arm to dig through the soil to water ice. Phoenix identified the chemical perchlorate, which is food for some microbes on Earth.

SPIRIT
10 June 2003 to 25 May 2011
Spirit was sent to Mars to analyse different rock and soil types. At its final location, in an area named 'Home Plate', it discovered that an ancient volcano had erupted on the planet.

VIKING PROGRAM
Viking 1: 20 August 1975 to 11 November 1982
Viking 2: 9 September 1975 to 12 April 1980
The main goals of this program were for the rovers to collect high-resolution images of the surface of Mars and analyse soil for any signs of life. The rovers detected unexpected chemical activity, but had no clear evidence of microbial life.

A Mars helicopter called Ingenuity was launched from the Perseverance rover

The Mars Reconnaissance Orbiter's camera captured these ripples in the dunes of Proctor crater, created by strong winds

DID YOU KNOW? Perseverance successfully made oxygen on Mars for the first time using carbon dioxide from the atmosphere

MAVEN
18 November 2013 to present
MAVEN was only designed to operate for two years. Launched with an aim to find out how Mars lost its atmosphere, it has since discovered rifts in the planet's upper atmosphere.

MARS RECONNAISSANCE ORBITER (MRO)
12 August 2005 to present
The MRO was sent to Mars to study its climate and geology. Its high-resolution camera, HiRISE, has captured detailed images of Mars. These include avalanches at Mars' north polar cap and its moon, Phobos.

MARS ODYSSEY
7 April 2001 to present
The main objective of Odyssey was to explore Martian terrain and determine if there are any radiation hazards that could impact human exploration. It has mapped the chemical and mineral distribution across the planet's surface.

INSIGHT
5 May 2018 to present
Launched with a seismometer to analyse the planet's interior, another main aim was to measure heat flow throughout Mars. On its 1000th day on Mars, InSight recorded the most powerful marsquake to date.

OPPORTUNITY
7 July 2003 to 13 February 2019
Launched the same year as Spirit, this rover searched for signs of life as we know it. Opportunity became the first rover to characterise sedimentary rocks on another planet. It also discovered a mineral called hematite, which often forms in liquid water.

CURIOSITY
26 November 2011 to present
Curiosity's mission is to discover if microbial life is – or could have been – supported on Mars. The rover has found sulphur, nitrogen, oxygen, phosphorus and carbon, suggesting that Mars once had the right chemistry to do so.

PERSEVERANCE
30 July 2020 to present
This rover is looking for previously habitable locations within Mars' Jezero crater. Perseverance will also test technology for future space travel and collect Mars samples that could be returned to Earth.

This image was taken just before sunset on Mars by Viking 1

© Alamy / NASA/JPL-Caltech/University of Arizona

ROGER CHAFFEE

The life of this skilled astronaut was cut short by a tragic accident

WORDS **AILSA HARVEY**

Since childhood, Chaffee had dreamt of going into space. When he was selected to be in NASA's third group of astronauts, Chaffee's goal became reality. Unfortunately, this would lead to tragedy, and he became one of the three fatalities of one of NASA's worst disasters. Less than a month before the maiden voyage, a flash fire killed the Apollo 1 crew as they underwent a preflight test on the launchpad. Chaffee didn't make it to space, but his achievements and the safety changes made after his mission are celebrated.

Chaffee was born in Michigan. He acquired his love of flying from his father, who had been a pilot. As a teenager, Chaffee was a keen scientist and mathematician, developing an interest in electronic engineering. Following high school, he began a naval scholarship at the Illinois Institute of Technology. However, after connecting his passions for science and flying, he soon decided to transfer to Purdue University in Indiana to study aeronautical engineering. After attaining his aeronautical engineering degree, Chaffee completed his naval training and became a pilot.

Chaffee's next goal was to train as an astronaut test pilot. He continued to gain experience in the navy, and in 1962 was selected as one of 1,800 candidates to take part in astronaut testing. A year later, 1,800 had been narrowed down to 271, and after passing many physical and psychological tests, Chaffee became one of NASA's new recruits.

Assigned to Project Gemini, which was dedicated to getting astronauts to the Moon before 1970, he was a 'capsule communications specialist'. This involved working with space equipment from ground stations. However, he was eventually promoted from ground station to spacecraft when he was selected as a crew member to fly into space. The mission was Apollo 1, then called AS-204. Putting his extensive training on land into practice, Chaffee was to be the chief communications expert, working alongside Gus Grissom and Ed White.

Chaffee took this role seriously, but instead of his training carrying him out of Earth's atmosphere, he ended up using it to report the disaster. When he and his colleagues were surrounded by flames during the preflight test, Chaffee continued to relay the conditions over the radio. Sadly, the situation couldn't be controlled, and none of the astronauts were able to escape. Although Chaffee's career and life were cut short, he remains one of NASA's most influential astronauts. He was dedicated to his duties until the very end, and his legacy transformed the Apollo program for the better.

Above: Gus Grissom (left), Ed White (centre) and Roger Chaffee (right) during Apollo 1 training

Right: Chaffee was selected as part of NASA Astronaut Group 3 in 1963

Right inset: In 1965, Chaffee (left) was taught how to use a lunar landing simulator by NASA scientist Maxwell W. Goode

5 THINGS TO KNOW ABOUT ROGER CHAFFEE

1 TRULY INSTRUMENTAL
During his childhood, Chaffee played the French horn, the cornet and the trumpet.

2 HONOURS
After his death, he was awarded a second Air Medal by the US Navy and the Congressional Space Medal of Honour.

3 CHAFFEE CRATER
A crater on the southern hemisphere of the Moon is named after him. Two nearby craters, called White and Grissom, are named after his crewmates.

4 FLIGHT TIME
During his time as a US Navy pilot, Chaffee spent more than 2,300 hours in the air.

5 PERSPECTIVE
One of Roger Chaffee's most famous quotes is: "Problems look mighty small from 150 miles up."

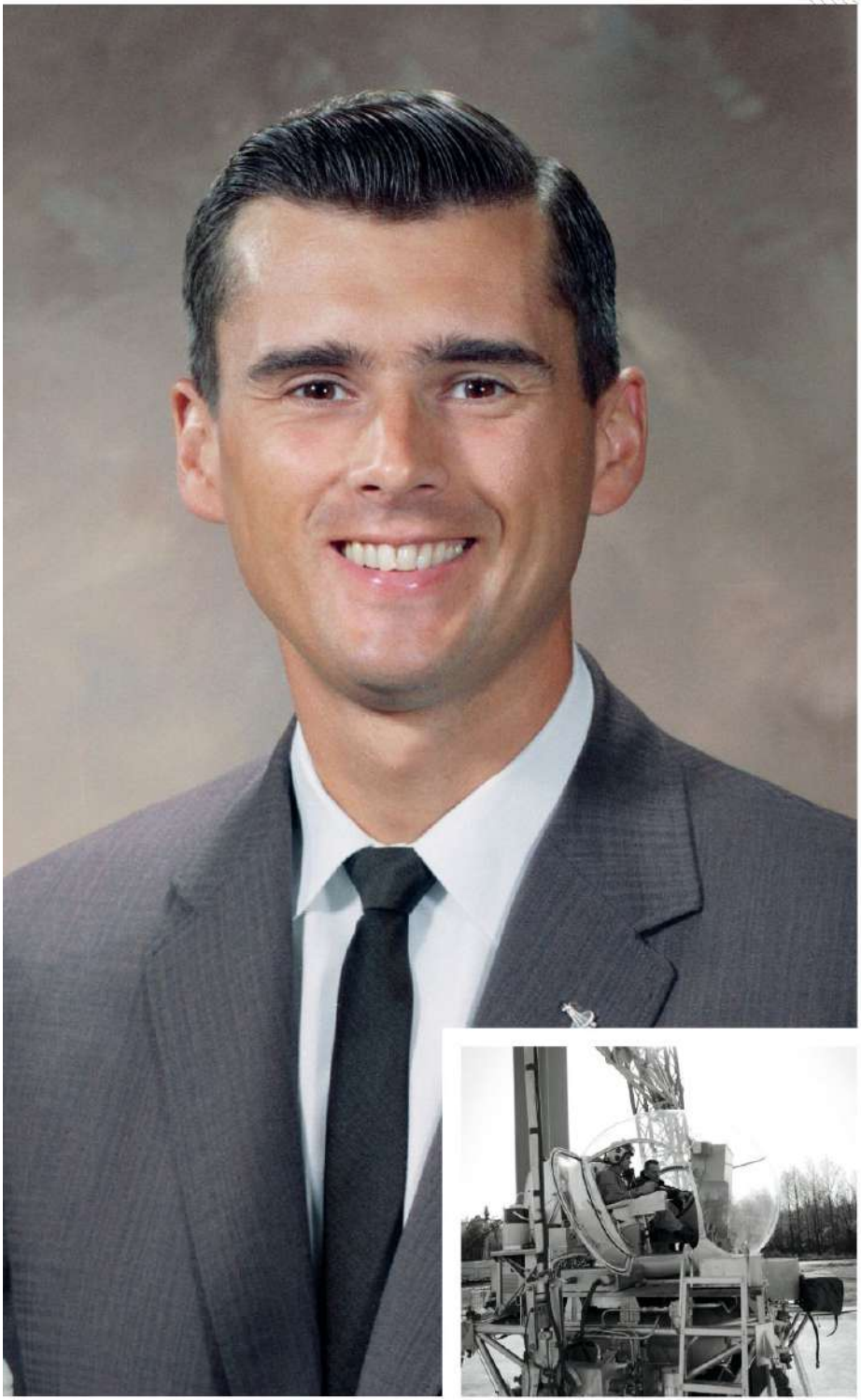
Did you know?
Flammable Velcro was used in the Apollo 1 capsule

The BIG idea

The main goal of the Apollo program was to land the first astronauts on the Moon

HOW THE TRAGEDY OF APOLLO 1 MADE THE MOON LANDING POSSIBLE

The fatal incident resulted in crucial safety changes. The capsule's hatch was altered so that the door could open outwards for a quick escape. During the Apollo 1 prelaunch, the cabin atmosphere was flammable oxygen. To reduce the chances of fires breaking out again, this was changed to a mixture of oxygen and nitrogen. The spacesuit that Chaffee died in was made of nylon. For the following Apollo missions, suits were changed to a non-flammable beta cloth. The safety of both the apparatus and testing procedures were subject to intense focus testing to ensure that the deaths of Chaffee and his crew members would help keep future crews safe.



A LIFE'S WORK

From air pilot to astronaut

1935
Chaffee was born on 15 February to Donald and Blanche Chaffee.

1942
At the age of seven, Chaffee travelled in an aeroplane for the first time.

1948
Chaffee joined his local Boy Scout group.

1953
He graduated from school in the top fifth of his class.

1954
Chaffee became a student at Purdue University, Indiana.

1954
In the summer, Chaffee spent eight weeks on naval duty.

1957
In his final university semester, Chaffee trained as an air cadet.

1959
Chaffee became one of the youngest pilots to fly an A3D.

1963
Chaffee was named by NASA as one of its new astronauts.

1966
He was selected for the first Apollo Earth-orbit mission.

1967
On 27 January, Chaffee died during the Apollo 1 launch test.

© NASA

COMMUNISM VS FASCISM

What are these two opposing ideologies?

WORDS **AILSA HARVEY**

FASCISM THROUGH THE YEARS

1919

The 'fascist era' began at the end of World War I, lasting until 1945, the end of World War II.

9 Nov 1921

Benito Mussolini founded the National Fascist Party.

1922

Benito Mussolini of Italy became the first fascist leader.

1933

The Nazis rose to power and introduced 'Volksgemeinschaft', the idea of creating one race in Germany.

1939

From 1939 to 1945, fascists in Italy and Germany tried to gain power over the rest of Europe.

1947

After WWII, most were against anything resembling Nazism. Fascist movements became small scale.

1970

Many anti-fascist and anti-racist groups were created in this decade, like the Anti-Nazi League.

DID YOU KNOW? Benito Mussolini was a fan of socialist Karl Marx before turning to fascism

Fascism and communism are two very different ideologies, but both claim to strive for 'perfection'. These images of perfection, however, are polar opposites. During the 20th century, fascism and communism went head to head. Both groups wanted to rebuild societies consistent with their utopian vision, acquiring as many followers as possible along the way. At their most extreme these dreams were inhumane, or faced problems in practicality when followed in the long term. Fascism is much less prevalent in modern society, but communist ideologies still survive in a handful of countries.

Communism is based on the idea that all people should have equal opportunities and wealth, while fascist governments have discriminated against different races and religions in order to favour a specific one. The totalitarian form of a fascist government places all authority in the hands of one dictator. These leaders have included Francisco Franco of Spain, who allowed no religion other than Catholicism, and Adolf Hitler, who focused on creating a one-race Germany with total disregard for all others. These are just two examples of the multiple fascist leaders who held warped perceptions of perfection.

Some communist governments of the past have proven to be equally as controlling. Typically, countries under communist rule are required to comply with its core ideologies. Communism aims to create equality among all people, but this has proven problematic to achieve. In contrast to capitalism, which allows individuals and organisations to earn a profit for their work, any properties or other earned resources in a communist state are owned by the government, to be redistributed more evenly. When personal reward is taken away, many believe that the incentive to achieve and to do so ethically is reduced. Meanwhile, extreme measures have been used in past communist governments to force compliance. This includes Joseph Stalin's rule of the Soviet Union between 1924 and 1953. During this time, it's estimated that he was responsible for the deaths of between 20 million and 60 million people.

Did you know?
The fasces was also a symbol in ancient Rome

WHAT IS FASCISM?

The word 'fascism' comes from the Italian 'fascio', meaning a bundle or group, and is considered a term for a militant brotherhood. The word 'fasces' means an axe tightly bound with sticks, an image that became a symbol of the fascist movement.

Fascism uses propaganda techniques to promote anti-liberalism – rejecting individual rights, civil liberties, free enterprise and democracy – anti-socialism – rejecting economic principles based on socialist frameworks – exclusion of certain groups and nationalism that seeks to expand the nation's influence and power.

Fascism promotes the concept of innate inequality and inescapable social hierarchies between groups. Underlying this hierarchy is the idea that a person's rank in society is determined by aspects of identity that are beyond their control, such as ethnicity or gender.

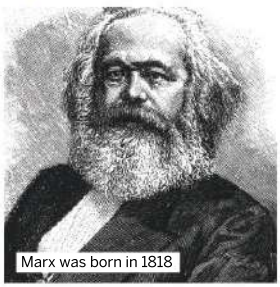
The fasces has been used as a symbol outside of fascism

FASCISM TODAY

After WWII, fascism as defined by Mussolini and Hitler's regimes largely fell out of fashion in Europe and North America. Nevertheless, there have been growing fascist movements in Europe and the US. Though many of the economic, social and political drivers of mid-20th-century European fascism were specific to that time and place, fascism's core ideas can still be found in modern populist movements that embrace hardline nationalism, white supremacy and xenophobia (fear of foreigners).

Most modern fascist movements are without official political party representation or state power, so they operate on a social movement framework rather than a political framework. Today's fascist movements also use more nuanced language, for example using the terms 'white separatism' and 'white self-determination'.

WHO WERE THE FOUNDERS?



Marx was born in 1818

Karl Marx

Published by Karl Marx in 1848, *The Communist Manifesto* became the basis of communism. In the manifesto, Marx called for a revolt against capitalism under the motto: "Workers of the world, unite!"

Mussolini was born in 1883

Benito Mussolini

Mussolini coined the term 'fascism' in 1921 when he created the first single-party fascist state. When he became the prime minister of Italy in 1922, Mussolini was able to put his extreme views into practice. 11 years later, Adolf Hitler – a fan of Mussolini – rose to power in Germany with ideologies similar to those Mussolini held.

© Alamy / Getty

ON THE MAP

Communist countries

Did you know?
China became a communist country in 1949

5 FORMS OF GOVERNMENT

1 DEMOCRACY
INDIA
Meaning 'rule by the people' in Greek, a democratic government allows citizens to vote for political leaders and other major decisions. India is the world's largest democracy, and has been so since 1950.

2 DICTATORSHIP
NORTH KOREA
One person or a small group holds absolute power over citizens. The leader of North Korea is Kim Jong-un, and since 1948 the country has been led by three men from the same family.

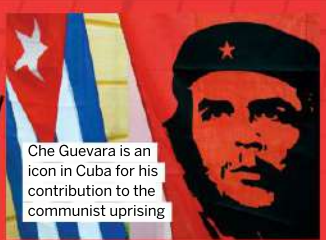
3 MONARCHY
QATAR
A monarch, which is usually a king or queen, is given power over a state. Qatar is an example of a hereditary monarchy, having been ruled by the Al Thani family since 1847.

4 SOCIALISM
N/A
In socialist countries, everyone equally owns factors of production, including farms, resources and money. Unlike in communism, it remains possible to own private property. Today, no country is completely socialist.

5 ARISTOCRACY
GREAT BRITAIN
An aristocratic government puts power into the hands of a small, privileged group. An example of this is the British monarchy. The royal family is given some power by the government to approve bills before they become law.

CUBA

Cuba has been a communist country since 1959, with the Communist Party of Cuba setting its policy. Miguel Díaz-Canel is the country's current president, and first secretary of the Communist Party of Cuba. While the government allows benefits such as education and healthcare being available to all, citizens have limited freedom, as they are forbidden from opposing the government. After 62 years of communism, poverty rates in the country have increased.



Che Guevara is an icon in Cuba for his contribution to the communist uprising

Vientiane, the capital of Laos, flying the national and communist flags together

LAOS

The Lao People's Revolutionary Party (LPRP) is the ruling party of Laos. The communist party altered its policies after the collapse of communist regimes in Europe, but has stayed focused on the values of Marxism. Like many of today's communist countries, the LPRP has significant control over social media use and punishes negative content against the party.

COMMUNISM THROUGH THE YEARS

1848
On 21 February, Karl Marx and Friedrich Engels shared *The Communist Manifesto.*

1917
Led by Vladimir Lenin, the Bolsheviks became the first communist government of the Soviet Union.

1921
On 1 July 1921, the Communist Party of China was created.

This communist statue is displayed in Jiangxi Province, China

CHINA

The country is led by the Chinese Communist Party (CCP). With around 85 million members, the CCP is one of the world's biggest political parties, and all elections take place internally. Every five years, 2,000 delegates of the National Congress meet to decide the Central Committee. This has 200 members, who are responsible for electing around 20 members of the political bureau. A select few of these 20 hold the highest authority beside China's leader.

WHAT IS COMMUNISM?

At its core, communism is an ideology of economic equality through the elimination of private property. The beliefs of communism centre on the idea that inequality and suffering result from capitalism. Under capitalism, private businesses and corporations own all the factories, equipment and resources, called 'the means of production'. These owners, according to communist doctrine, can then exploit workers, who are forced to sell their labour for wages.

The working class, or proletariat, must rise up against the capitalist owners, or bourgeoisie, according to the ideals of communism, and institute a new society with no private property, no economic classes and no profits. Communism differs from socialism, though the two have similarities. Both advocate economic equality and state ownership of various goods and services. Socialism usually works through the existing democratic structures of capitalist countries; most capitalist countries have some socialist characteristics.

Red was chosen as the colour of communism to represent the blood of those in the battle against capitalism

VIETNAM

Governed by the Communist Party of Vietnam, this country has Southeast Asia's fastest growing economy. Between 1975 and the late 1980s, Vietnam only traded with other communist countries. However, after the downfall of the Soviet Union, Vietnam began trading with other countries. Although it is communist, Vietnam has adopted capitalist principles such as support of entrepreneurs, which has helped boost its economy.

Vietnam's largest city is named after communist leader Ho Chi Minh

1924

Lenin died on 21 January, and Joseph Stalin took his place.

1945

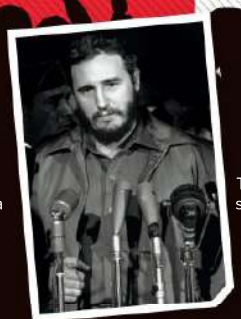
Korea was divided during World War II, with North Korea becoming communist.

1947

US president Harry Truman called for communism to be contained.

1959

Fidel Castro took over Cuba to make it a communist state.



1989

The Berlin Wall, which separated West Berlin from the communist East Berlin, was destroyed.

1991

On 25 December, the Soviet Union came to an end, along with communism in the majority of countries.

© Alamy / Getty

WONDERS OF THE LYCURGUS CUP

How the Romans used nanotechnology to transform this ancient chalice

WORDS: SCOTT DUTFIELD

Sitting in the British Museum is a Roman glass chalice, around 1,600 years old, that can appear in two different colours. Known as the Lycurgus Cup, the chalice appears jade green at first glance, and depicts a scene of King Lycurgus being dragged to the underworld by the god Ambrosia from Greek mythology. However, when light is shone from behind the glass, its green colour suddenly changes to a blood red. This shift in colour baffled scientists for years, until the 1990s, when researchers uncovered that Roman glassmakers had used nanomaterials to create the cup's unique effect.

Nanoparticles of two metals are suspended in the glass: 66.5 per cent of them silver and 31.2 per cent gold. The size of these particles, which at 50 nanometres are around 100 times smaller than the width of a human hair, and their dodecahedral shape result in the shift in colour, known as dichroism. Electrons of the silver and gold nanoparticles vibrate when exposed to different wavelengths of white light. The resonating electrons will then re-emit that light with the same colour wavelength. With a combination of silver and gold, those wavelengths of colour are in the green and red range.

While some believe that the inclusion of these metals may have been a fluke, it's commonly accepted that their inclusion was deliberate. As a result, glassmakers during the 4th century could have been the first to develop nanotechnology.

Did you know?

Nanoparticles are used in modern paints

STAINED WITH NANOTECHNOLOGY

The Romans may have been the first to use nanotechnology to colour their glass, but they certainly weren't the last. Long before the term 'nanotechnology' had even been coined, Medieval artisans used nanoparticles of gold and silver to colour panes of glass from around the 10th century. Although not always mixed together to create the same dichroism effect of the Lycurgus Cup, nanoalloys seen in stained-glass windows around the world were used to create glittery 'lustres' in ceramic glazes until the 17th century in Asia, before the technology moved to Europe.

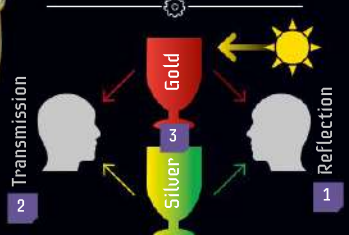
Silver and gold were used to colour windows in churches

When light comes from behind the Lycurgus Cup, it appears red

The Lycurgus Cup was created during the 4th century CE by Roman glassmakers

SHIFTING COLOURS

How the Lycurgus Cup changes from green to red



REFLECTION

1 When light reflects off nanoparticles of silver, they appear green, whereas gold nanoparticles will appear brown instead.

TRANSMISSION

2 When light shines through a medium containing these nanoparticles, silver nanoparticles appear yellow and gold nanoparticles appear violet.

DICHROISM

3 The silver and gold in the cup's glass create its shift between jade green, when light is reflected upon it, and blood red, when light is passed through it.

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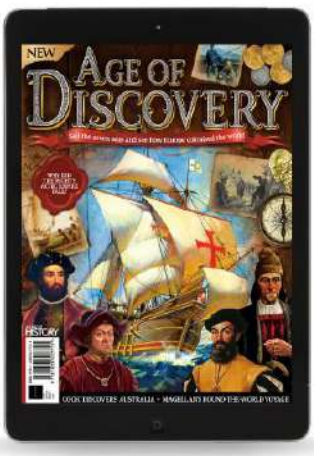

Age of Discovery

Imagine a map where the borders of Europe are detailed and defined, but the fringes of Africa and Asia are barely sketched out… they simply fade into nothingness. The Age of Discovery changed all that. Europeans set out to explore the globe, encountering other advanced civilisations. In **All About History Age of Discovery**, you'll meet the people responsible for colonising the globe and examine the profound, far-reaching consequences of European exploration that still resonate today.

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ELECTRICITY BASICS

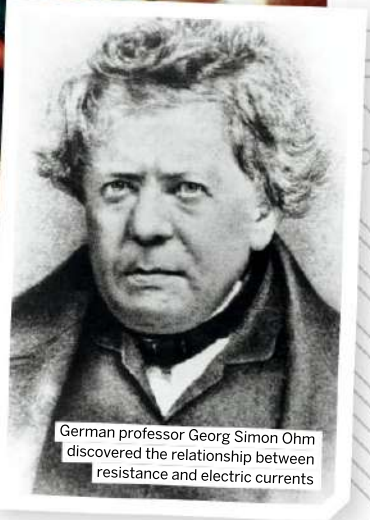
The science of resistance, inductance and capacitance

WORDS JIM LUCAS

Electronic circuits are an integral part of nearly all the technological advances being made in our lives today. Television, radio, phones and computers immediately come to mind, but electronics are also used in vehicles, kitchen appliances, medical equipment and industrial controls.

At the heart of these devices are active components, or components of the circuit that electronically control electron flow, like semiconductors. However, these devices couldn't function without much simpler, passive components that predate semiconductors by many decades. Unlike active components, passive components such as resistors, capacitors and inductors can't control the electron flow with electronic signals.

DID YOU KNOW? When subjected to an electric field, electrons travel in a conductor at around a millimetre per second


German professor Georg Simon Ohm discovered the relationship between resistance and electric currents

RESISTANCE

As the name implies, a resistor is an electronic component that resists the flow of electric current in a circuit. In metals such as silver or copper, which have high electrical conductivity and therefore low resistivity, electrons are able to skip freely from one atom to the next, with little resistance.

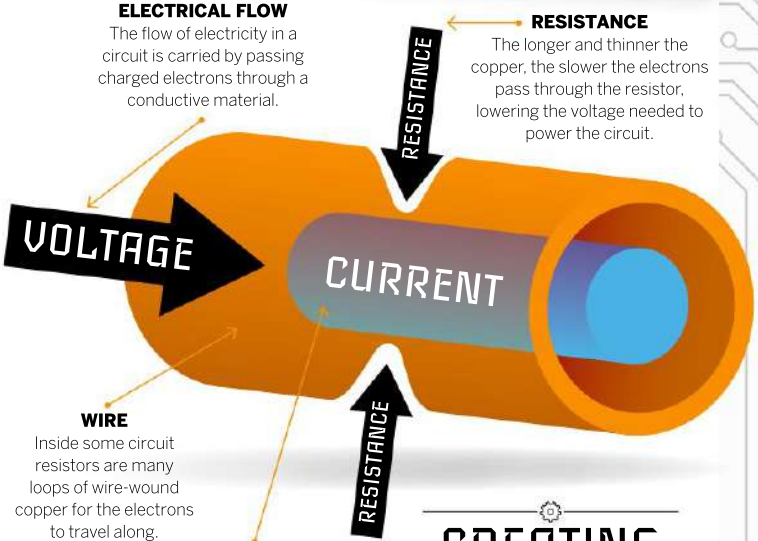
The electrical resistance of a circuit component is defined as the ratio of the applied voltage to the electric current that flows through it. The standard unit for resistance is the ohm, which is named after German physicist Georg Simon Ohm. This is defined as the resistance in a circuit with a current of one ampere at one volt. Resistance can be calculated using Ohm's law, which states that resistance equals voltage divided by current.

Resistors are generally classified as either fixed or variable. Fixed-value resistors are simple passive components that always have the same resistance within their prescribed current and voltage limits. They are available in a wide range of resistance values, from less than one ohm to several million ohms. Variable resistors are simple electromechanical devices, such as volume controls and dimmer switches, which change the effective length or effective temperature of a resistor when you turn a knob or move a slide control.

Did you know?
Electricity travels at the speed of light

ELECTRICAL FLOW
The flow of electricity in a circuit is carried by passing charged electrons through a conductive material.

RESISTANCE
The longer and thinner the copper, the slower the electrons pass through the resistor, lowering the voltage needed to power the circuit.



WIRE
Inside some circuit resistors are many loops of wire-wound copper for the electrons to travel along.

CONVERSION
Resistors convert the energy of the electrical voltage into other forms of energy, such as thermal.

CREATING RESISTANCE

How resistors slow down the flow of electrons in a circuit

© Getty / Alamy

CAPACITANCE

These devices store charge

Capacitance is the ability of a device to store electric charge; the component that stores charge is called a capacitor. The simplest consist of two flat conducting plates separated by a small gap. The potential difference, or voltage, between the plates is proportional to the difference in the amount of the charge on the plates. Capacitance is the amount of charge that can be stored per unit of voltage. The unit for measuring capacitance is the farad (F), named for physicist Michael Faraday, and is defined as the capacity to store one coulomb of charge with an applied potential of one volt. One coulomb (C) is the amount of charge transferred by a current of one ampere in a second.

To maximise efficiency, capacitor plates are stacked in layers or wound in coils with a very small air gap between them. Dielectric materials – insulating materials that partially block the electric field between the plates – are often used within the air gap. This allows the plates to store more charge without arcing and shorting out.

Capacitors are often found in active electronic circuits that use oscillating electric signals, such as those in radios and audio equipment. They can charge and discharge nearly instantaneously, which allows them to be used to produce or filter certain frequencies in circuits. An oscillating signal can charge one plate of the capacitor while the other plate discharges, and then, when the current is reversed, it will charge the other plate while the first plate discharges.

Did you know?
A spark of static can measure up to 3,000 volts

In general, higher frequencies can pass through the capacitor, while lower frequencies are blocked. The size of the capacitor determines the cutoff frequency for which signals are blocked or allowed to pass. Combinations of capacitors can be used to filter selected frequencies within a specified range.

Stronger supercapacitors are manufactured using nanotechnology to create super-thin layers of materials, such as graphene, that achieve capacities that are 10 to 100 times that of conventional capacitors of the same size. However, they have much slower response times than conventional dielectric capacitors, so they can't be used in active circuits.

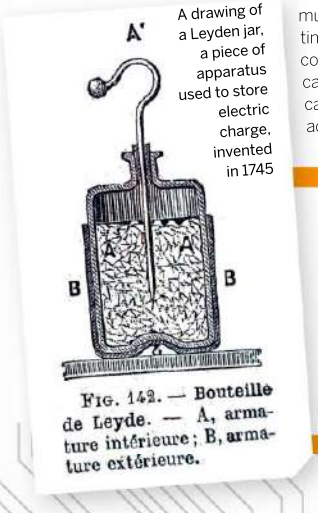


Fig. 142. — Bouteille de Leyde. — A, armature intérieure; B, armature extérieure.

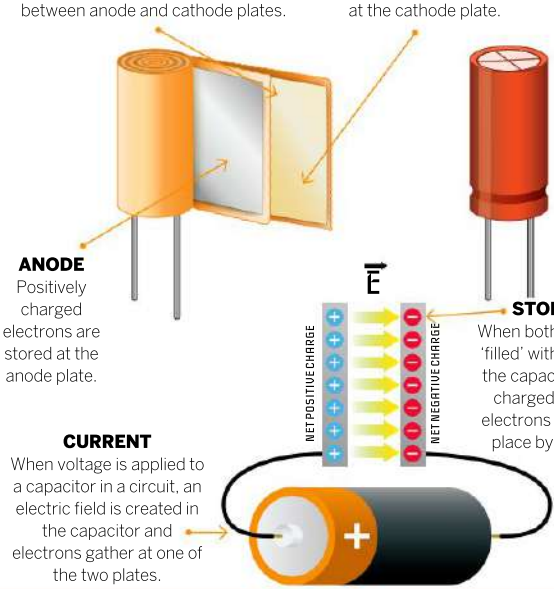
A drawing of a Leyden jar, a piece of apparatus used to store electric charge, invented in 1745

CREATING A CAPACITOR

How does this device hold a small reserve of energy?

DIELECTRIC MATERIAL
Often ceramic, dielectric material prevents electrons from crossing between anode and cathode plates.

CATHODE
Negatively charged electrons are stored at the cathode plate.



ANODE
Positively charged electrons are stored at the anode plate.

STORAGE
When both plates are 'filled' with electrons the capacitor is fully charged, and the electrons are held in place by the field.

CURRENT
When voltage is applied to a capacitor in a circuit, an electric field is created in the capacitor and electrons gather at one of the two plates.

INSIDE THE LEYDEN JAR

The earliest example of a capacitor is the Leyden jar. This device was invented to store a static electric charge in conducting foil that lined the inside and outside of a glass jar. The jar was created by Ewald von Kleist and Pieter van Musschenbroek, both working independently during the early 1740s. Musschenbroek was a teacher at the University of Leiden in The Netherlands, and so named this device the Leyden jar. The glass jar housed two sheets of foil that acted as conductors – one on the outside of the jar and the other lining it. A metal chain connected to an iron rod extended through a wooden lid with a ball at the end. When a charge was applied to the conductors, the electrons were temporarily trapped and stored.

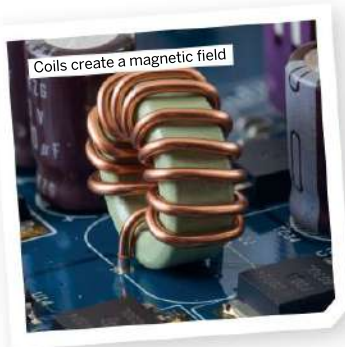
DID YOU KNOW? A typical lightning flash is around 300 million volts and 30,000 amps

INDUCTANCE

An inductor is an electronic component consisting of a coil of wire with an electric current running through it, creating a magnetic field. The unit for inductance is the henry (H), named after Joseph Henry, an American physicist who discovered inductance independently at about the same time as English physicist Michael Faraday. One henry is the amount of inductance that's required to induce one volt of electromotive force – the electrical pressure from an energy source – when the current is changing at one ampere per second.

One important application of inductors in active circuits is that they tend to block high-frequency signals while letting lower frequency oscillations pass. This is the opposite function of capacitors. Combining the two components in a circuit can selectively filter or generate oscillations of almost any desired frequency.

With the advent of integrated circuits, such as microchips, inductors are becoming less common, because 3D coils are extremely difficult to fabricate in 2D-printed circuits. For this reason, microcircuits are designed without inductors, instead using capacitors to achieve essentially the same results.


Coils create a magnetic field

"They block high-frequency signals while letting lower frequency oscillations pass"

A SHOCKING DISCOVERY

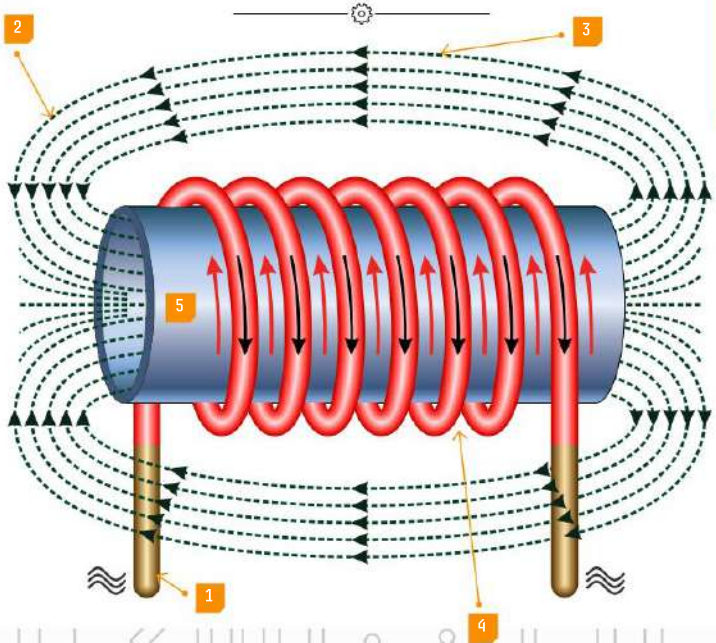
American author, scientist and diplomat Benjamin Franklin is often credited as the discoverer of electricity after flying a kite during a lightning storm. His iconic experiment involved him attaching a wire to the top of a kite – which was a precursor to the lightning rod – tied to a hemp string, which would have been made sodden by the rain, and a silk string for Franklin to hold. Although it's a misconception that the lightning hit the kite directly, the flying experiment produced a spark felt by Franklin, and the fibres of the hemp string stood erect, much like the hairs on your arm when you rub it with a balloon.

Franklin demonstrated the connection between lightning and electricity, but he was not the first. Thousands of years ago, the ancient Greeks carried out static electrical experiments using fur and amber. And in Iraq around 2,000 years ago, jars called Baghdad Batteries used sheets of copper and an iron rod to attempt to create light.

Benjamin Franklin flying a kite during a thunderstorm in 1752

INSIDE AN INDUCTOR

How a magnetic field can support a circuit



1 WIRE
An electrical current is passed through a copper wire, and a magnetic field, or flux, is generated around it.

2 MAGNETIC FIELD DIRECTION
The magnetic field follows the direction that the current is flowing. When the current changes direction, so does the magnetic field.

3 ENERGY OUTAGE
When the current is turned off, the energy stored in the magnetic field will continue to supply power, but only for a short period of time.

4 POWER UP
The greater the amount of current passed through the coil, the larger the magnetic field produced.

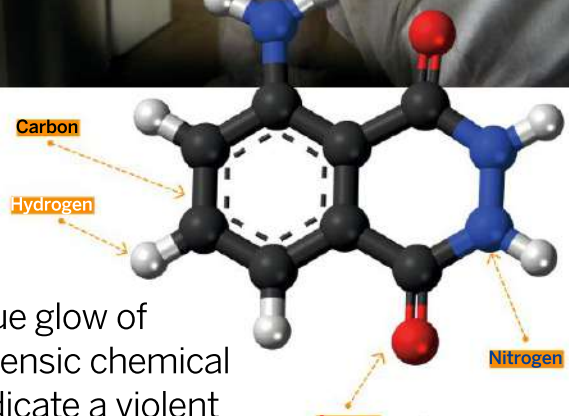
5 CORE
Copper wires are commonly wrapped around a non-conductive material, such as plastic.

© Getty / Alamy / Shutterstock

Did you know?
Biologists use luminol to help with research

HOW LUMINOL WORKS

The blue glow of this forensic chemical can indicate a violent crime has taken place



WORDS **JO ELPHICK**

Police may well believe that a serious crime has taken place, but without any obvious signs of violence, their investigation could come to a grinding halt. That's when the scene of crime officers step in to look for seemingly invisible clues. Criminals often attempt to clean up a crime scene by mopping up any spilt blood, but just because you can no longer see it doesn't mean it isn't there, and a quick spray of luminol can often reveal the gory details.

Forensic scientists began using the luminol test in 1942, having discovered that when the chemical compound came into contact with an oxidising agent, such as blood, it caused luminescence. The eerie blue glow highlights where blood has been spilt, and often lights up other vital clues through the blood stain patterns, such as how the crime was committed, if a body was moved and how the perpetrator left the crime scene. Since tiny particles of blood can cling to surfaces for many years, even older crime scenes can benefit from the luminol test.

The science behind this amazing forensic investigator's tool is very similar to that of a simple glow stick. Luminol powder, made up of carbon, hydrogen, oxygen and nitrogen, is mixed with a number of other liquid chemicals which react with the iron in haemoglobin, instigating a process known as 'chemiluminescence'. When the room is plunged in darkness, the telltale blue glow reveals any bloodshed.

Although luminol is a useful aid to the forensic team, it isn't always helpful. Substances other than blood can cause the ghostly luminosity, such as the sodium chlorate in bleach or even certain enzymes in faeces. It is therefore vital that any chemiluminescence that occurs is followed up with another test to make sure blood has been found.

Above left: A violent criminal may have cleaned the area, but luminol still finds traces of blood

Above: Police forensics at work on a crime scene, spraying a door handle with luminol to reveal certain substances under ultraviolet light

THE HUBER MURDER CASE

In 1994, John Joseph Famalaro was taken in for questioning after a body was discovered in his home. Police investigated his previous addresses, including a warehouse he once owned in Orange County. The place appeared clean, but when luminol was sprayed across the walls, it lit up. The warehouse was covered in blood. After DNA samples had been removed and analysed, it was confirmed that the blood belonged to Denise Huber, who had gone missing three years earlier.

A bottle of luminol spray, like that used in the case

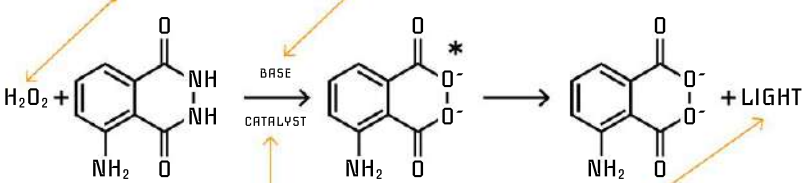
DID YOU KNOW? German chemist H. O. Albrecht first discovered luminol's glow in 1928

THE SCIENCE OF CHEMILUMINESCENCE

It looks like a ghoulish magic trick, but how does it work?

1 THE OXIDISING AGENT
A strong oxidising agent such as hydrogen peroxide is added to the luminol, also known as 5-amino-2,3-dihydro-1,4-phthalazinedione.

2 THE BASIC SOLUTION
A basic liquid solution is made by adding an alkali – sodium hydroxide – to the luminol, which can now be poured into a spray bottle.



3 DETECTING THE CATALYST
A catalyst is required to accelerate the reaction between the luminol and hydrogen peroxide, such as the iron found in haemoglobin.

4 THE BLUE GLOW
Luminol loses nitrogen and hydrogen during the reaction and gains oxygen atoms, which releases energy. Any excess energy appears as photons of light.

LUMINOL TRIGGERS

LUMINESCENCE IN NATURE

Some living things are capable of producing their own light, known as bioluminescence. The angler fish lures its prey in by dangling a glowing line, enticing smaller fish to come closer. Other predators of the deep stun their prey by emitting a sudden flash of light, confusing them. The pulsing lights of insects signal they're ready to mate, while some mushrooms glow to encourage moths to land on them and spread their spores. Like luminol, bioluminescence occurs through a chemical reaction. However, unlike the forensic investigative tool, bioluminescence requires the chemical luciferin.

"The eerie blue glow highlights where blood has been spilt"

5 FACTS ABOUT LUMINOL

1 BLINK AND YOU'LL MISS IT
The chemiluminescent glow will not last very long after the luminol has been applied. In fact, it starts to fade after approximately 30 seconds.

2 1:1,000,000
Luminol is so sensitive that it can identify the presence of blood at a dilution of up to one part in a million, which means even the tiniest speck can be detected.

3 HOLD THE SAUCE
Unfortunately for forensic investigators working in a kitchen crime scene, luminol also begins to glow when it comes into contact with the peroxidase enzymes found in horseradish.

4 CONFIRMED BY A SECOND TEST
Since the luminous reaction can occur with a number of other substances, scene of crime officers may also carry out a phenolphthalein test to confirm the presence of blood.

5 IMITATING NATURE
The strange glowing phenomenon that occurs when luminol is sprayed onto a bloodstain can also be seen in the insect world with glow worms and fireflies.

© Getty / Alamy / Pioneer Forensics LLC / Wiki: Jynto

WHY YOUR HEART BEATS

See inside the pump at the core of our bodies and explore its crucial role

WORDS BAHAR GHOLIPOUR

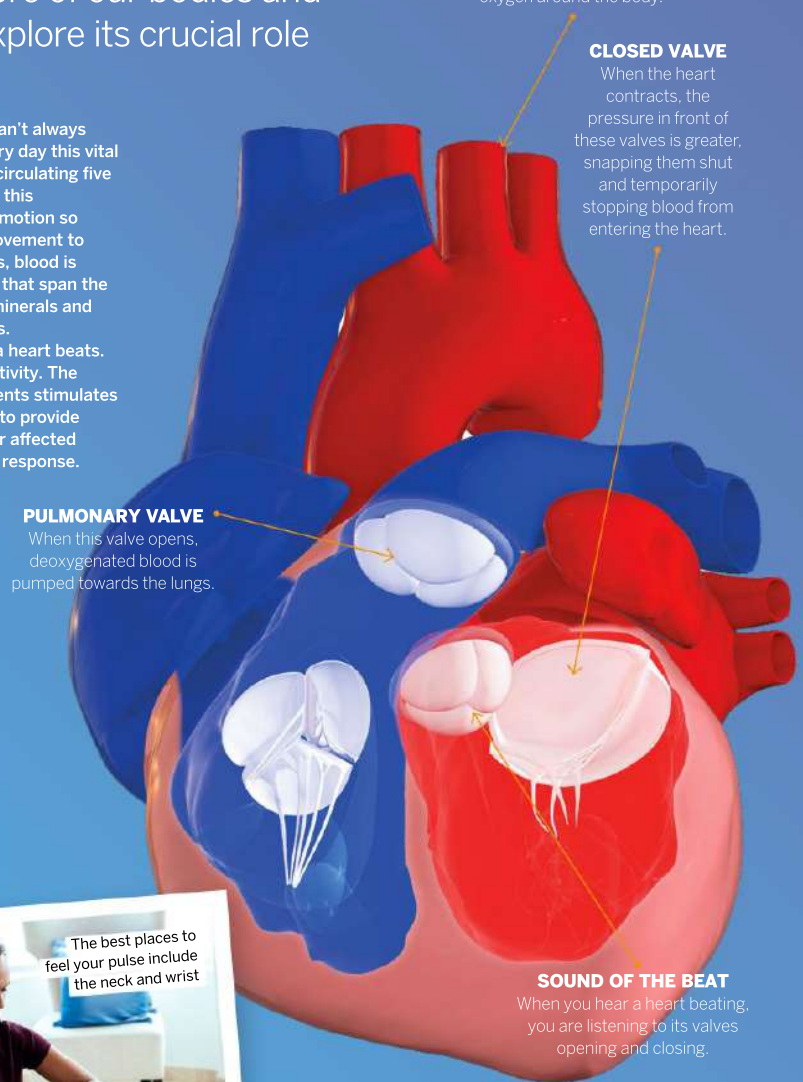
The heart is your body's engine. You can't always hear it, and you rarely feel it, but every day this vital organ beats around 100,000 times, circulating five litres of blood around your body. It is this transportation that makes the heart's pumping motion so essential. Every cell in the body relies on this movement to receive oxygen and nutrients. As the heart beats, blood is pushed along the 99,420 miles of blood vessels that span the body, carrying glucose, amino acids, vitamins, minerals and fatty acids to cells and removing waste products.

Several factors can change the rate at which a heart beats. These include stress, pain, illness or physical activity. The adrenaline released in the body during these events stimulates heart cells to beat faster. This happens in order to provide more oxygen and nutrients to muscles and other affected areas in short bursts – part of the fight-or-flight response.

MONITORING YOUR HEART RATE

Heart rate, also known as a pulse, is the number of times a heart beats per minute. It varies between people, but a normal range for adults is 60 to 100 beats per minute. A normal heart rate depends on the individual, age, body size, heart conditions, whether the person is sitting or moving, medication use and even air temperature. Emotions can affect heart rate: getting excited or scared can increase it. Getting fitter lowers the heart rate by making heart muscles work more efficiently. An athlete may have a resting rate of 40 to 60 beats per minute. Knowledge about your heart rate can help you monitor your fitness level, and it may help you spot developing health problems.

The best places to feel your pulse include the neck and wrist



CONTRACTION
A contracting heart pushes blood out through the aorta to deliver oxygen around the body.

CLOSED VALVE
When the heart contracts, the pressure in front of these valves is greater, snapping them shut and temporarily stopping blood from entering the heart.

PULMONARY VALVE
When this valve opens, deoxygenated blood is pumped towards the lungs.

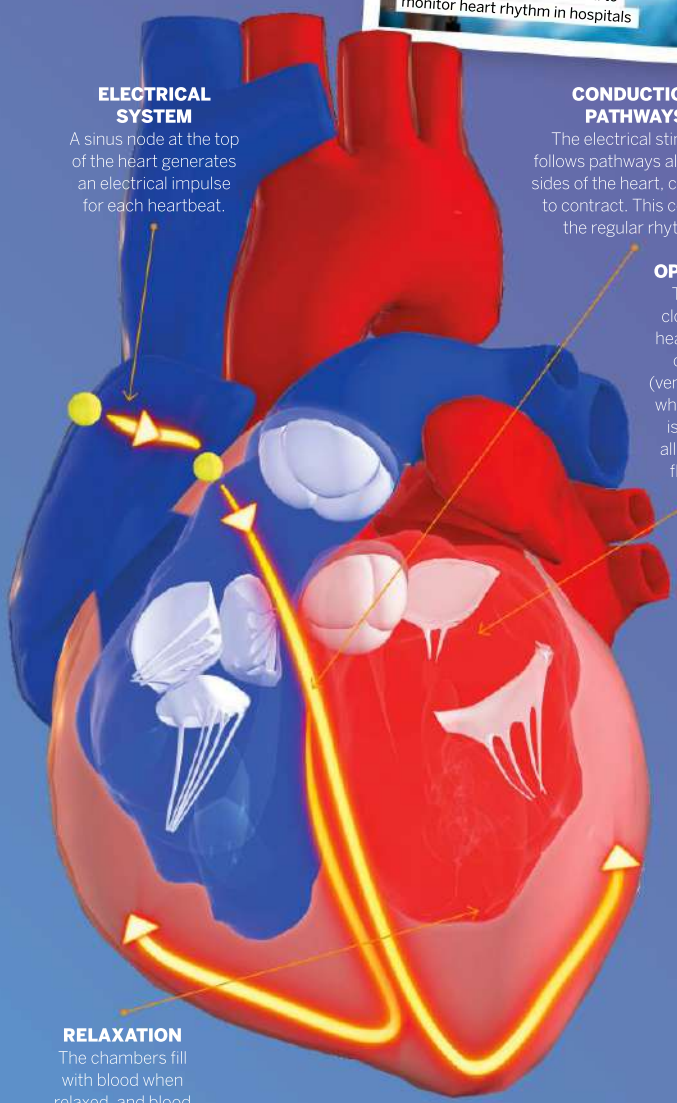
SOUND OF THE BEAT
When you hear a heart beating, you are listening to its valves opening and closing.

DID YOU KNOW? Women's hearts usually beat slightly faster than men's

HEART MECHANICS

How is this organ structured to maintain a steady rhythm and blood flow?

Electrocardiograms are used to monitor heart rhythm in hospitals



ELECTRICAL SYSTEM
A sinus node at the top of the heart generates an electrical impulse for each heartbeat.

CONDUCTION PATHWAYS
The electrical stimulus follows pathways along two sides of the heart, causing it to contract. This controls the regular rhythm.

OPEN VALVE
The valves closest to the heart's bottom chambers (ventricles) open when the heart is relaxed to allow blood to flow inside.

RELAXATION
The chambers fill with blood when relaxed, and blood pressure is lowered.

BLOOD'S JOURNEY

Blood is constantly passing through the heart through four main openings: the pulmonary artery, pulmonary vein, aorta and vena cava. When the oxygen from blood has been used up, the deoxygenated blood travels into a chamber on the heart's right side – the atrium. Blood from the upper body enters via a blood vessel called the superior vena cava, while blood returning from the lower body flows through the inferior vena cava. The heart then contracts, forcing blood out of the right atrium and into a lower chamber called the ventricle. As this ventricle contracts, blood is pumped through the pulmonary artery and to the lungs, where it will pick up oxygen and release carbon dioxide to be expelled from the body. After visiting the lungs, oxygen-rich blood is ready to be sent around the body. It returns to the heart into the left atrium, where the same contractions provide the energy to send it out through the aorta and around a network of arteries throughout the body.

AR zone

SCAN HERE

Scan the QR code to track blood's movement through the heart

Smart watches can measure heart rate by detecting the amount of blood flowing through the wrist

© Getty / Alamy

CENTRIFUGAL VS CENTRIPETAL

There's a dizzying difference between these forces of circular motion

WORDS JIM LUCAS

Centrifugal force is ubiquitous in our daily lives, but is it what we think it is? We experience it when we round a corner in a car or when an aeroplane banks into a turn. We see it in the spin cycle of a washing machine or when people ride on a carousel. One day it may even provide artificial gravity for spaceships and space stations. But centrifugal force is often confused with its counterpart, centripetal force, because they are so closely related – essentially two sides of the same coin.

Centripetal force is defined as the force necessary to keep an object moving in a curved path which is directed inward towards the centre of rotation, while centrifugal force is defined as the apparent force felt by an object moving in a curved path that acts outwardly away from the centre of rotation. While centripetal force is an actual force, centrifugal force is defined as an apparent force. In other words, when twirling a mass on a string, the string exerts an inward centripetal force on the mass, while mass appears to exert an outward centrifugal force on the string.

Both centrifugal and centripetal are the same force, but experienced in different directions. If you are observing a rotating system from the outside, you see an inward centripetal force acting to constrain the rotating body to a circular path. However, if you are part of the rotating system, you experience an apparent centrifugal force pushing you away from the centre of the circle, even though what you are actually feeling is the inward centripetal force, which is keeping you from going off on a tangent.

Above: Centripetal force keeps the carriage on a roller coaster moving in a circular motion around a loop

Above right: Hammer throwers utilise centripetal acceleration to launch metal balls

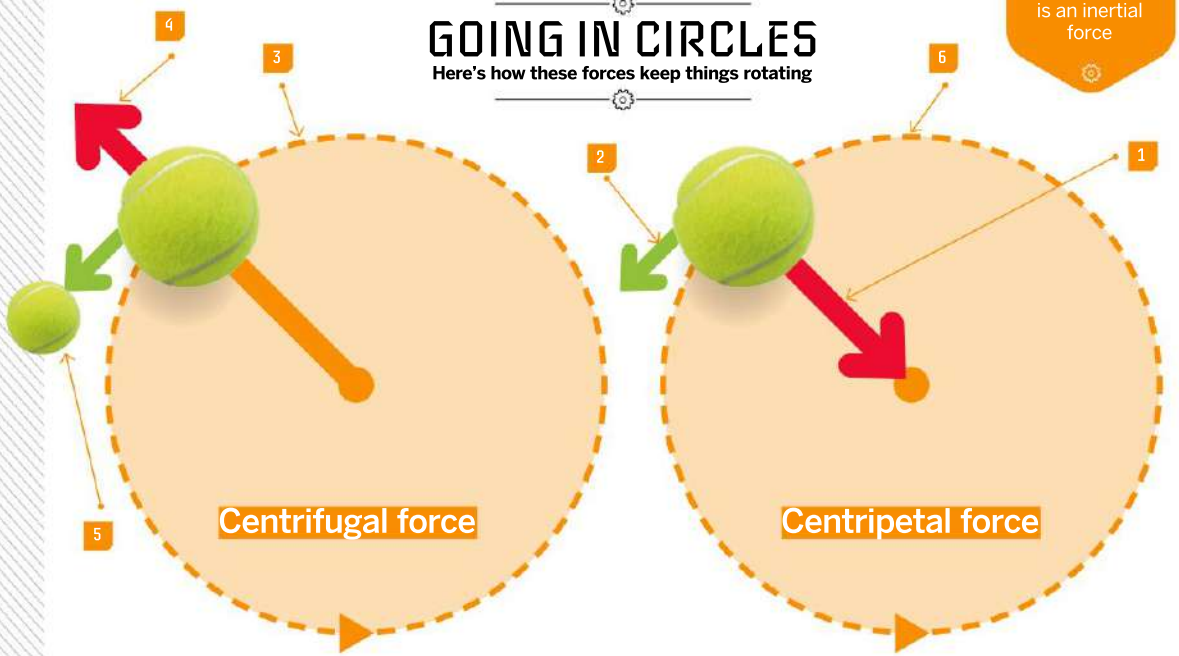
This apparent outward force is described by Newton's laws of motion. Newton's first law states that a body at rest will remain at rest, and a body in motion will remain in motion unless it is acted upon by an external force. If a massive body is moving through space in a straight line, its inertia will cause it to continue in a straight line unless an outside force causes it to speed up, slow down or change direction. In order for it to follow a circular path without changing speed, a continuous centripetal force must be applied at a right angle to its path.

Newton's third law states that for every action, there is an equal and opposite reaction. Just as gravity causes you to exert a force on the ground, the ground appears to exert an equal and opposite force on your feet. When you are in an accelerating car, the seat exerts a forward force on you just as you appear to exert a backward force on the seat. In the case of a rotating system, the centripetal force pulls the mass inward to follow a curved path, while the mass appears to push outward due to its inertia. In each of these cases, there is only one real force being applied, while the other is only an apparent force.

Did you know?
Centrifugal force is an inertial force

GOING IN CIRCLES

Here's how these forces keep things rotating



1 CENTRIPETAL FORCE
This is a force that pulls an object towards the centre of a circle.

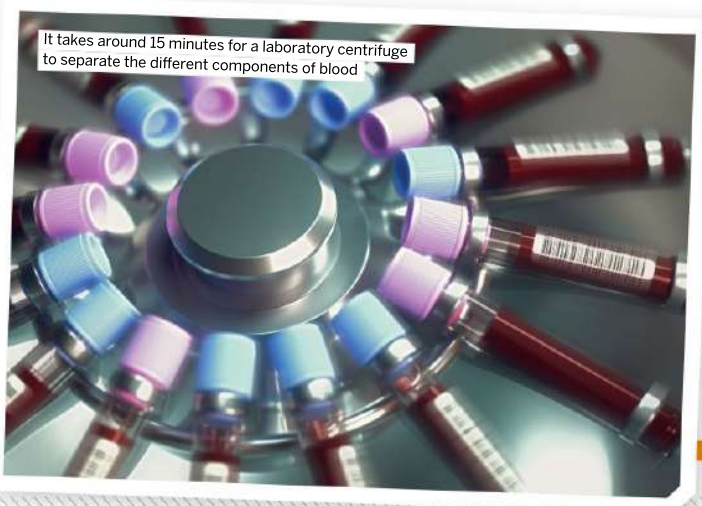
2 VELOCITY
When an object's velocity is perpendicular to the direction a force is applied, such as tension on a rope, it will move in a circle.

3 ACCELERATION
The centripetal force increases if an object is moved closer to the centre of the circle.

4 CENTRIFUGAL FORCE
This is the outward force generated when an object is being rotated.

5 TANGENTIAL DIRECTION
If the force keeping an object in rotation is broken, such as cutting the string that holds a spinning ball, the object will fly off in a straight line, following the tangential direction.

6 INERTIA
According to Newton's first law, an object will constantly move in a straight line unless acted upon by another force, such as the tension of a spring, friction on a road or the pull of gravity.



It takes around 15 minutes for a laboratory centrifuge to separate the different components of blood

SPUN BLOOD

Centripetal force is used in a laboratory centrifuge to accelerate the precipitation of particles suspended in liquid. One common use of this technology is for preparing blood samples for analysis. Under the normal force of gravity, thermal motion causes continuous mixing, which prevents blood cells from settling out of a whole blood sample. However, a typical centrifuge can achieve accelerations that are 600 to 2,000 times that of normal gravity. This forces the heavy red blood cells to settle at the bottom and stratifies the various components of the solution into layers according to their density.

© Getty / Alamy

INSIDE THE ATARI 2600

This groundbreaking console spawned a new era of home entertainment

WORDS **MARK SMITH**

It's hard to imagine now, but this little black box was a trailblazing piece of technology, giving rise to the games consoles we know and play today. Atari, founded in 1972, was among the first video game companies, and produced *Pong*, the first successful arcade game. In the early 1970s, video games had become popular in amusement arcades, but the idea of having them at home was pretty unusual. But that was about to change. Fairchild Camera and Instrument introduced the Channel F system, the first cartridge-based home video game system, in 1976, and in 1977 Atari launched the Video Computer System (VCS), which would later be renamed the 2600.

Unlike early home computers, which were designed mainly for practical purposes such as word processing, consoles were all about fun. The 2600 was designed to be plugged straight into the TV, and the games had no loading times. Primitive by today's standards, it boasted a 1.19MHz 8-bit processor, 128 bytes of RAM and two-channel mono sound, and retailed for $199 – equivalent to $849 today, or about £615. Although there were only nine games available when it was launched, it quickly came to dominate the fledgling industry, selling over 30 million units and hundreds of millions of games.

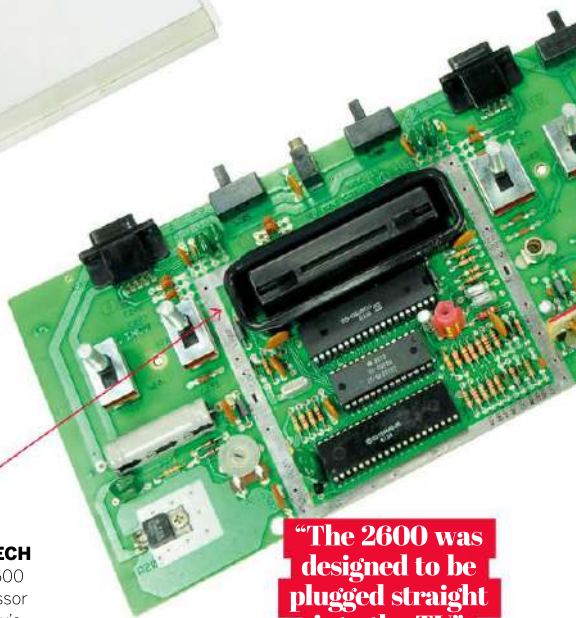
In the 1980s the console cemented its place as a must-have piece of home entertainment gear with the release of the iconic *Space Invaders*. The game was so popular that people were buying the console just to play that one game. Today the Atari 2600 still has a large number of fans, with some games still being produced today by hobbyist developers.

UNDER THE COVER

The early console was packed with then-revolutionary home technology

TV CONNECTOR LEAD
There was no need for a monitor. By using this lead, any TV could be used to display the games on screen.

METAL PROTECTION
A metal box fitted between the circuit board and case ensured the console was pretty robust.



MICROPROCESSOR TECH
The circuit board of the 2600 was based on microprocessor technology – the company's first venture in the field.

"The 2600 was designed to be plugged straight into the TV"

DID YOU KNOW? The global video game market is set to reach £185 billion ($253 billion) by 2025, with over 2.5 billion gamers worldwide

GAME RESET SWITCH
When things got tough, users could reset the console with the flick of a switch.
GAME SELECT SWITCH
Players could change difficulty levels by alternating between A and B game settings.
POWER SWITCH
Activating the console was pretty straightforward, with a solitary switch and no complex or long-winded boot-up processes.
VIDEO COMPUTER SYSTEM
HARDWOOD DESIGN
It's not very often you find a piece of tech with wooden components, but the early 2600 had a hardwood finish.
CARTRIDGE SLOT
While some early consoles had games built in, the 2600 used removable game cartridges instead.
The console was unusual since it used cartridge-based technology rather than built-in games
The Atari 2600 underwent a redesign, with some switches moved to the back of the console
RIGHT CONTROLLER
POWER ADAPTER
LEFT CONTROLLER
PITFALL!
SPACE SHUTTLE
STAR WARS: THE EMPIRE STRIKES BACK

WHAT WAS IN THE BOX?

The first VCS units came with everything a person needed to start playing straight out of the box: two joysticks, a single pair of paddles and the two-player *Combat Cartridge*, which contained several tank and plane action games. Unlike the big launches of today, there weren't a whole lot of games available when it first hit the shelves. Besides the *Combat Cartridge*, there were just eight other game titles available at launch. A few of them were based loosely on Atari's popular arcade games. The games available were *Air-Sea Battle*, *Basic Math*, *Blackjack*, *Indy 500*, *Star Ship*, *Street Racer*, *Surround* and *Video Olympics*.

WHAT IS THE DARKNET?

Why the internet we see is just the tip of the iceberg

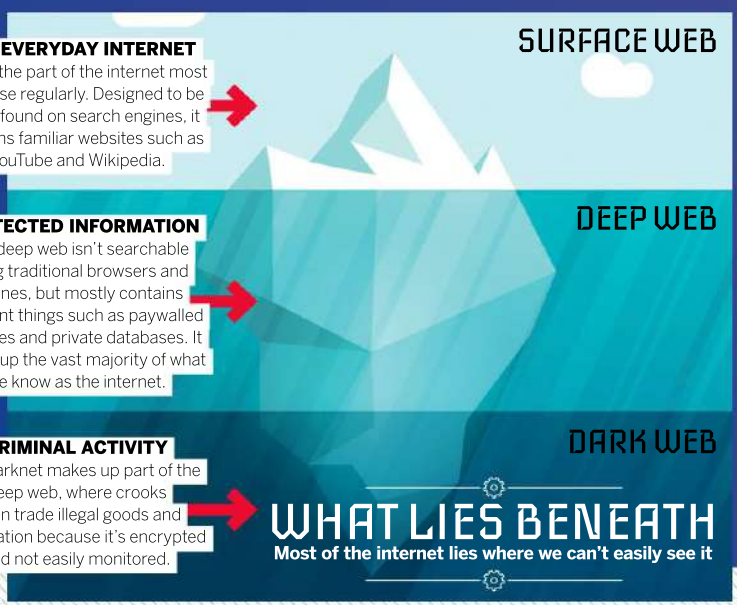
The biggest part of the internet isn't easy to find

WORDS MARK SMITH

From checking out the latest music videos on YouTube to looking up information on Wikipedia, for most of us, using the internet is something we do every day. But underneath the internet we can all see – what we term the surface web – is the one most of us don't ever see. It's called the deep web, and it's huge. Just like the biggest part of an iceberg sits under the waterline, so does the deep web lie beneath the surface web. In fact, it dwarfs the surface web, accounting for 90 per cent of all the information on the internet. But what's the difference between the two?

The biggest difference is how we find the websites. On the surface web, search engines like Google are designed to find the site we're looking for when we type a search term into a box. They do this by indexing them with computer programs called crawlers, which visit each site and store their locations for future reference. Most websites on the surface web can be accessed using traditional browsers like Chrome, Firefox and Internet Explorer, and the websites on there usually end in .co.uk, .org or .com. This is because the people who design these websites want us to find them. But the deep web is made up of the parts of the internet that aren't found by search engines, though for a variety of reasons. For example, deep web sites could be concealed behind passwords or security walls, while others don't have visible links so that they can't be found and indexed by crawlers.

Did you know?
Over 30 per cent of Americans access the dark web regularly


SURFACE WEB
DEEP WEB
DARK WEB
THE EVERYDAY INTERNET
This is the part of the internet most of us use regularly. Designed to be easily found on search engines, it contains familiar websites such as YouTube and Wikipedia.
PROTECTED INFORMATION
The deep web isn't searchable using traditional browsers and engines, but mostly contains innocent things such as paywalled websites and private databases. It makes up the vast majority of what we know as the internet.
CRIMINAL ACTIVITY
The darknet makes up part of the deep web, where crooks often trade illegal goods and information because it's encrypted and not easily monitored.
WHAT LIES BENEATH
Most of the internet lies where we can't easily see it

CYBERCRIME

What makes the darknet a big draw for crooks is anonymity. It's a digital space that the police and big internet providers have no control over. For this reason, it's a place where criminals can trade illegal goods and services, such as hackers for hire. One example of illegal activity was the Silk Road, a digital black market named after the famous Silk Road that connected Asia to Europe. This allowed people to sell drugs, engage in money laundering activities and more. Launched in 2011, it was shut down by the FBI two years later, and its founder is now serving a life sentence.

In 2019, the Wall Street Market was shut down by German police. It had been a place to trade illicit services – ranging from fake documents and stolen credit card details to malicious software. Last year American officials reported that 179 people were arrested and more than $6.5 million (£4.8 million) was seized in a worldwide crackdown on illegal activities on the darknet as part of an operation called DisrupTor.

US deputy attorney general Jeffrey Rosen, FBI director Christopher Wray and Drug Enforcement Agency acting administrator Timothy Shea announce operation DisrupTor

DID YOU KNOW? 90 per cent of posts on dark web forums are buyers looking to contract someone for cybercrime

Not everything on the deep web is necessarily sinister, and often these sites just contain files such as academic journals, financial reports or legal files, as well as things like internal company intranets, chat messages and paywalled news websites that require payment in order to access them. But they can be open to some unscrupulous activity such as software piracy or illegal streaming of sports events.

Part of the deep web can be a much more sinister place, and that's referred to as the darknet, or dark web. The terms deep web and darknet are often mixed up, but they're not the same thing. The darknet is a part of the hidden deep web that is used by criminals, hackers and terrorists, among others, to conduct secret communications away from prying eyes, as well as trade illegal goods. It's only accessible using specialist software, and makes up a much smaller part of the deep web – just 0.01 per cent. A big danger of the darknet to those who venture there is that it has many more – and more serious – cyberthreats, with ransomware and botnet malware among other viruses that pose a risk to unwary visitors.

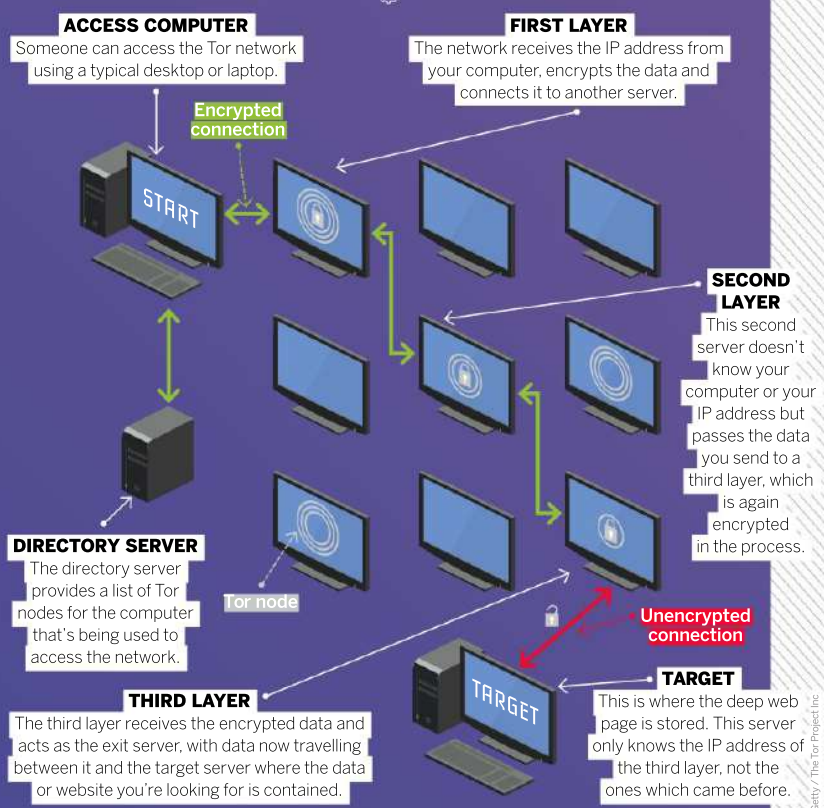
GETTING ACCESS

Because it's not designed to be found, getting access to the darknet is done using specialist software. Instead of using regular browsers, anyone heading to the darknet uses something called The Onion Router (Tor) hidden service protocol. Tor has multiple layers of connectivity, enabling users to stay anonymous. Once they access the server, someone using the darknet isn't looking at websites on interconnected servers, but sites that are all self-contained on the network. While ordinary sites have addresses ending in terms like .com, these dark web sites end with .onion.

The Onion Router (Tor) network server guarantees anonymity

HOW DOES THE TOR NETWORK WORK?

The Onion Router allows people to access the hidden darknet


ACCESS COMPUTER
Someone can access the Tor network using a typical desktop or laptop.
FIRST LAYER
The network receives the IP address from your computer, encrypts the data and connects it to another server.
Encrypted connection
START
SECOND LAYER
This second server doesn't know your computer or your IP address but passes the data you send to a third layer, which is again encrypted in the process.
DIRECTORY SERVER
The directory server provides a list of Tor nodes for the computer that's being used to access the network.
Tor node
Unencrypted connection
TARGET
This is where the deep web page is stored. This server only knows the IP address of the third layer, not the ones which came before.
THIRD LAYER
The third layer receives the encrypted data and acts as the exit server, with data now travelling between it and the target server where the data or website you're looking for is contained.
TARGET

Most of the deep web is pretty innocent and contains things such as chat messages and financial reports
As well as illegal goods, the darknet contains a lot of cyberthreats
MALWARE

© Getty / The Tor Project Inc

Protective eyewear needs to be worn when using a plasma cutter because of the extremely bright light emitted

HOW PLASMA CUTTERS WORK

The science behind these efficient metal-slicing tools

WORDS **AILSA HARVEY**

Heat has the ability to change the state of matter. It can melt a solid into a liquid and evaporate a liquid to become a gas. The fourth state of matter is plasma. When matter is heated to extreme temperatures, gases can become ionised. This means a gas' atoms lose their electrons, giving them a positive charge.

Plasma cutters are tools that use this hot plasma to cut through metal. As plasma has high energy, it travels in fast streams out of the plasma cutter. As it does, it carries electrical energy created inside the machine and transfers it onto metal. The plasma produced can reach temperatures far hotter than the surface of the Sun, at over 20,000 degrees Celsius.

When the high-energy plasma comes into contact with the metal, it reverts to its original gaseous state. In doing this it releases the extreme heat it was carrying. This heat melts the metal to cause a break in the targeted area. Plasma cutters are often handheld tools, giving the user control of where the cuts are made.

At this scrap metal recycling facility, metal is being cut into smaller, flat pieces

© Getty / Alamy / Illustration by Adrian Mann

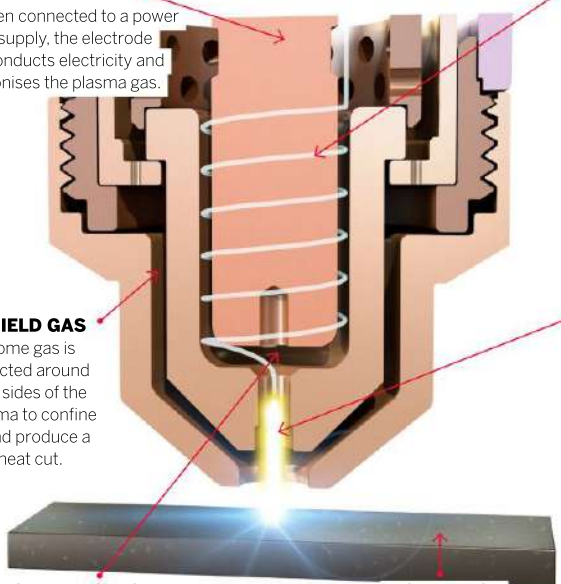
WHO USES THEM?

There are many industries in which cutting metal is required. These range from locksmiths, who help to cut open locked safes and vaults, to workers in metal recycling plants, who break up metal into small, manageable pieces. Any repair work on metal would also benefit, such as the repair of cars and farm equipment. Aside from these industrial applications, plasma cutters are popular for creative uses. They are commonly used by metal artists to create intricate metal structures. The cutting precision of these tools increases the level of detail that can be produced with metal.

This detailed metal sculpture is being cut using a plasma cutter

CREATING A CUT

How these tools use gas and electricity to shape metal



ELECTRODE
When connected to a power supply, the electrode conducts electricity and ionises the plasma gas.

PLASMA GAS
Oxygen, argon or nitrogen flows around an electrode towards the nozzle.

PLASMA STREAM
As the ionised gas forms around the nozzle, it creates a path between the electrode and the work piece for the electric current.

SHIELD GAS
Some gas is directed around the sides of the plasma to confine it and produce a neat cut.

CREATING A SPARK
A spark first forms between the electrode and the nozzle, causing some of the gas to become ionised.

WORK PIECE
The conductive metal is melted by the electric energy, while the ionised gas pushes the molten metal away for a clear cut.

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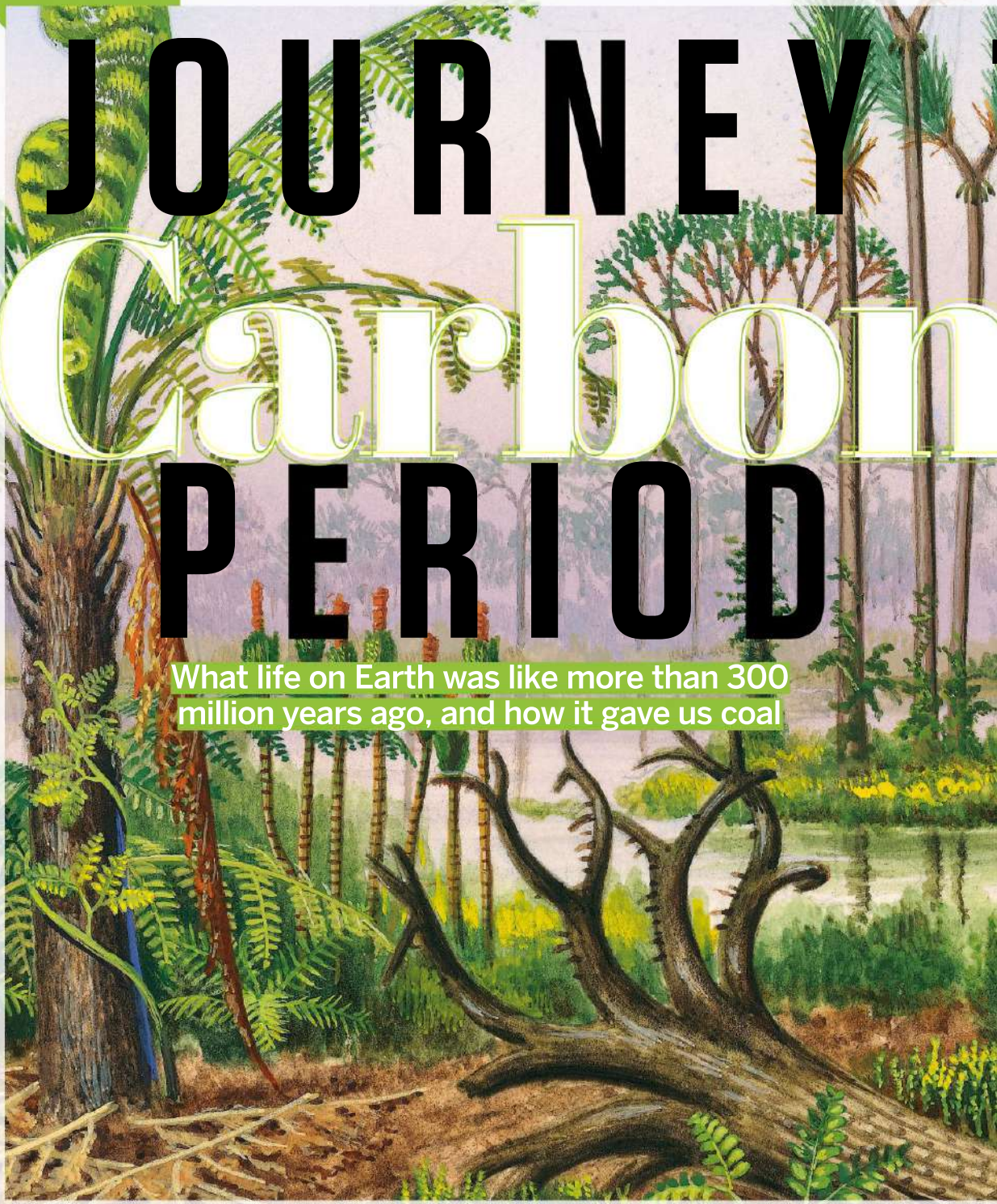
JOURNEY TO THE Carboniferous PERIOD

What life on Earth was like more than 300 million years ago, and how it gave us coal



DID YOU KNOW? There are 1.06 trillion tonnes of coal reserves worldwide

T O THE
iferous

Mariopteris muricata, extinct seed-bearing ferns which flourished 300 million years ago

WORDS **SCOTT DUTFIELD**

Did you know?
Coal ignites at around 300 degrees Celsius

The Carboniferous Period occurred between 359 and 299 million years ago during the late Paleozoic Era. The period gets its name from the amount of carbon-rich coal that formed as a result of the decomposition of vast swamps and forests that covered the Earth's surface during this time.

It's commonly divided into two subperiods: the early Carboniferous, called the Mississippian, and the late Carboniferous, called the Pennsylvanian. The division of the period is due to the work of two scientists. Alexander Winchell discovered an outcrop of early Carboniferous geological strata in the Mississippi Valley in 1870. Another geologist, Henry Shaler Williams, uncovered similar but younger strata in Pennsylvania in 1891. Both Winchell and Williams' discoveries were separated by a geological unconformity, a layer of rock that breaks the chronology of the rock strata – therefore the subperiods remain in use, particularly in North America.

During the Carboniferous Period, the Earth's continental arrangement would have looked very different to today's continents, but climates were still cold at the poles and humid at the equatorial regions. If you were to observe the Carboniferous Earth from space, the equator would be filled with lush tropical rainforests. The world's continents had moved primarily into the Southern Hemisphere, and there was relatively little land in the Northern Hemisphere.

Large amounts of frozen water stored in the ice caps lowered global sea levels, exposing large areas of flat wetland habitats

© Alamy / Getty

Coal is set to last as an energy source until 2090

A fossil of *Aphthoroblattina*, a 50-centimetre-long prehistoric cockroach

that would have been previously covered by water. Over time, muddy wetlands were transformed into rainforests, which eventually turned into massive peat bogs. This allowed many species to move out of the water and diversify into some of the largest insects to ever exist.

In the preceding Devonian Period, life in the oceans exploded in diversity. It was the 'Age of Fishes' before a mass extinction event reduced species on Earth by around 75 per cent. The species that remained continued to evolve, both in and out of the water. Due to an influx in oxygen from an eruption of plant life, the Carboniferous produced some of the largest arthropod species – invertebrates with an exoskeleton – to ever roam the Earth.

Flora during this period consisted predominantly of plant species similar to those found in the modern-day tropics and in humid climates. Early relatives of vascular plants – now extinct – created the first forests during the Carboniferous Period. Conifers, ferns and early trees, along with clubmosses, horsetails and other seed-bearing plants, were the species that made up the first forests.

This boom in forest biomes saw the dawn of the 'Age of Oxygen'. The ability of these early plants to photosynthesise light and carbon dioxide into oxygen led to a rise in its concentration in the air. During the Carboniferous, oxygen made up 35 per cent of the atmosphere at its peak, compared to the 21 per cent of modern-day levels. This increase had a knock-on effect on the size of the species that evolved. Arthropods, along with some other vertebrate species, began evolving larger bodies as a result of the hyperoxygenated atmosphere.

> **"The equator would be filled with lush tropical rainforests"**

One theory as to why insects in particular experienced gigantism is due to anatomy. All arthropods, including insects, have an open circulatory system. This means that their 'blood', known as hemolymph, is not confined to blood vessels and freely moves around the body. However, this system isn't the most efficient way to deliver oxygen to tissue. Tiny openings on an insect's body, called spiracles, allow oxygen from the atmosphere to enter its open circulatory system. The oxygen then travels down tubular structures called tracheoles before ultimately diffusing into bodily tissue. This makes insects very responsive to changes in atmospheric oxygen levels. Modern-day studies have shown that when insects are raised in oxygen-restricted environments, they are smaller than the average insect raised under normal atmospheric conditions. It's believed that under the heightened oxygen levels of the Carboniferous Period, insect tracheoles could diffuse more oxygen into the body, allowing them to grow larger.

Did you know?
Arthropleura had as many as 30 pairs of legs

Earth's forests were filled with dog-sized scorpions and millipedes as long as a king-sized bed at the height of the Carboniferous. But it wasn't just insects and arthropods that became giants during this time; some salamander-like animals called *Diplocaulus* reached lengths up to two

INVENTING THE EGG

This period saw one of the largest leaps in the evolution of vertebrate species with the 'invention' of the amniote egg around 340 million years ago. Amniotes, a group of animals that includes reptiles, birds and some mammals, produce an egg with a tough protective shell and a series of life-supporting membranes that surround the developing offspring within. Before the amniote egg, fish and amphibians could only lay their eggs in water. However, as reptiles began to evolve and created tougher eggs that could be laid anywhere on dry land, the amniote egg was born. This ability to give birth out of the water was one of the main factors that facilitated further diversity of life on Earth.

The first hard-shelled eggs were around 280 million years before chickens evolved

metres, and some sail-finned pelycosaurs stretched to more than three metres.

Around 290 million years ago, a change in global climate and continental shifts likely caused the collapse of the Carboniferous forests, marking the end of the period. Like many other geological periods, the Carboniferous ended with a mass extinction event throughout tropical rainforests around the world. Forest coverage shrank globally by around 53 per cent due to changes in the environment and climate. This event is sometimes referred to as the Kasimovian crisis. However, the exact cause for the crisis remains debated. There is evidence that the Earth warmed and global ice retreated by the end of the period, but it remains unclear whether this change in temperature can fully explain the collapse of the Carboniferous rainforests. Some rainforests did persist through the crisis, entering into the Permian period which followed.

Most of the world's coal resources were formed from the vegetation that sprouted during the Carboniferous Period. Coal is created when plant matter is submerged in water and mud and then experiences compression and heat over hundreds of millions of years, in a process called coalification. As plant life in the Carboniferous forests and swamps died away and decomposed, the organic matter gradually piled on top of other forest debris and was buried by sediment. This burial was caused by ongoing tectonic and erosive processes in nature. As the decomposed plant matter was compressed by mounting layers of rock and then heated, it formed peat, the first stage in the coal-making process.

Over millions of years, the increased pressure from piling layers of rock and the heat from the Earth's core striped it of its hydrogen, oxygen and nitrogen, leaving mostly carbon behind and transforming the peat into coal. Peat experiences temperatures of around 227 degrees Celsius on its journey through coalification.

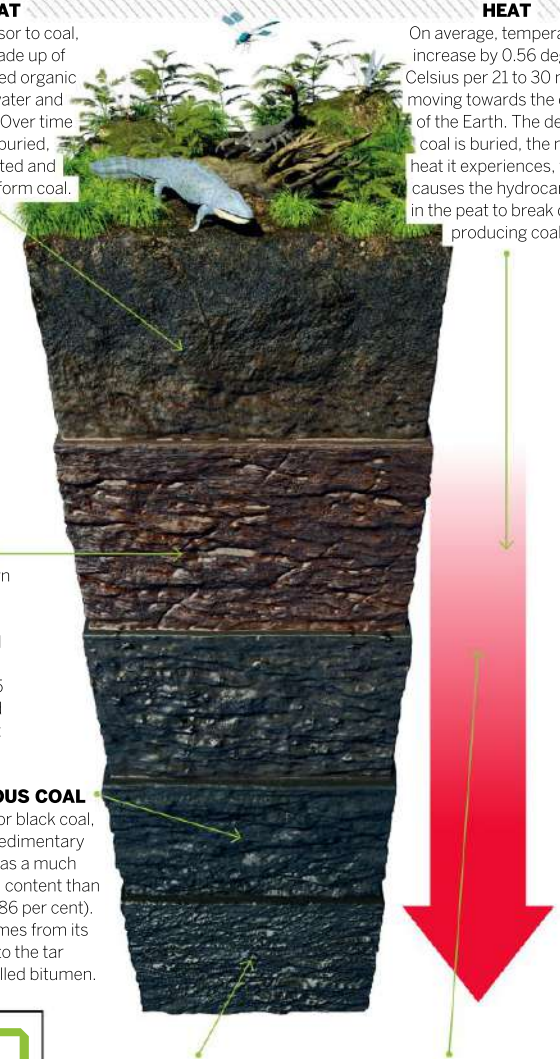
Carboniferous rock can be spotted as alternating layers of sandstone, shale and coal

MAKING COAL

How different types of coal are made

PEAT
The precursor to coal, peat is made up of decomposed organic matter, water and sediment. Over time peat is buried, compacted and heated to form coal.

HEAT
On average, temperatures increase by 0.56 degrees Celsius per 21 to 30 metres moving towards the centre of the Earth. The deeper coal is buried, the more heat it experiences, which causes the hydrocarbons in the peat to break down, producing coal.



LIGNITE
Also known as brown coal, lignite is the lowest ranked coal type as a fossil fuel due to its low carbon content (25 to 35 per cent) and high water content (66 per cent).

BITUMINOUS COAL
Bituminous, or black coal, is a dense sedimentary rock that has a much higher carbon content than lignite (45 to 86 per cent). Its name comes from its likeness to the tar substance called bitumen.

ANTHRACITE
This coal has the highest content of carbon (around 97 per cent). With almost no water, and carbon dioxide expelled from it, this hard rock is filled with tiny pores which make it useful in water filtration.

PRESSURE
Pressure applied by mounting sediment compacts peat. At the lignite stage of the coalification process, water is squeezed out.

AR zone

SCAN HERE

© Alamy / Getty / Illustration by Nicholas Forder

LIFE IN THE CARBONIFEROUS FOREST

Meet some of the giant creatures that roamed the rainforests

Did you know?
Coal beds can be up to 12 metres thick

DIPLOVERTEBRON
This species is one of the earliest to bear reptilian traits. However, they didn't produce an amniotic egg. *Diplovertebron* are believed to be early anthracosaurs, eel-like amphibians which evolved to lay amniotic eggs and are thought to be one of the first groups of tetrapods (four-legged vertebrates) to colonise land.

ARTHROPLEURA
Arguably the largest arthropod to ever march on land, these mega millipedes meandered through the forests, growing to lengths of around 2.6 metres. There's no evidence to suggest they had carnivorous teeth, and the presence of plant spores in their fossilised faeces suggest these arthropods maintained a herbivorous diet.

DID YOU KNOW? Average global temperatures during the Mississippian Carboniferous were around 20 degrees Celsius

MEGANEURA
The biggest dragonfly to ever zip through the air, *Meganeura* had a wingspan up to 71 centimetres and spent its time patrolling the forest on the hunt for prey. Like most giant insect species at the end of the Carboniferous, these megabugs became extinct following climatic change and altering habitats.

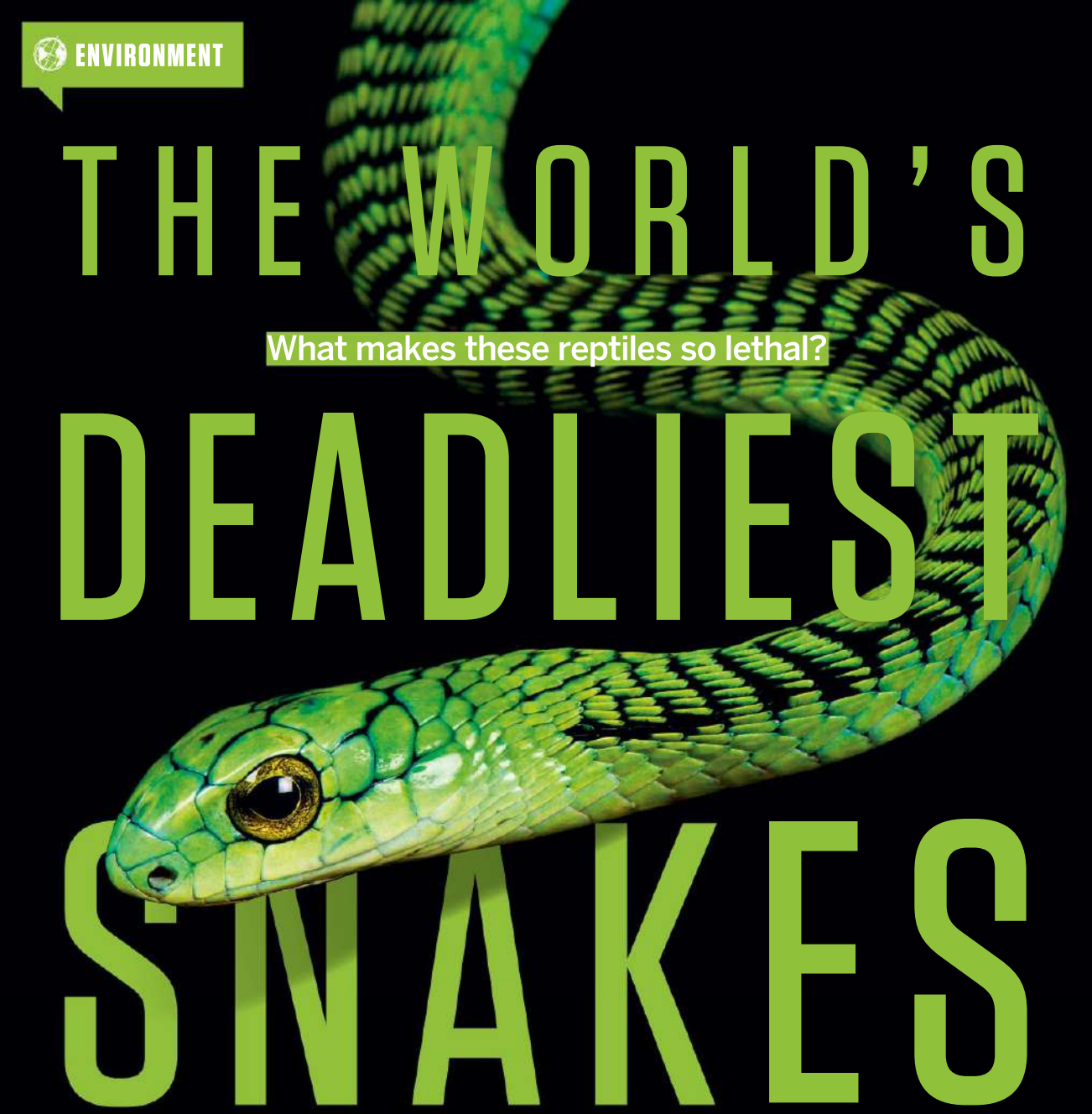
VASCULAR PLANTS
The swamps and forests were filled with the first vascular plants – which can transport minerals and water throughout themselves – including seed ferns, clubmosses and equisetidae. Equisetidae are notably jointed at the stem, with spirally arranged leaves at the joints. All equisetidae are extinct except for the horsetail rush, found in North America, Europe and Asia.

PULMONOSCORPIUS
Stretching 70 centimetres from pincer tip to tail, these megascorpions were not to be messed with. Along with powerful pincers, this armed arthropod sported a sting, or telson. However, the potency of its venom remains a mystery. The *Pulmonoscorpius* is also known as the breathing scorpion due to the evolution of its book lung, resembling the pages of a book.

© Illustration by Nicholas Forder

THE WORLD'S DEADLIEST SNAKES

What makes these reptiles so lethal?



WORDS AILSA HARVEY

They hiss, they slither and – unfortunately for humans and unsuspecting prey – they bite. Snakes bite approximately 5.4 million people every year, resulting in around 81,000 to 138,000 deaths. Venomous snakes kill their victims with toxic substances produced in a modified salivary gland, which the animal then injects into prey using its fangs. Snake venom has evolved over millions of years to cause severe reactions in the victim, from immobilisation and haemorrhage to tissue death and inflammation. Here are some of the world's deadliest snakes; their venom not only packs a punch for small prey, it can also be fatal to humans.

DID YOU KNOW? In India, around 58,000 deaths are attributed to snakebites every year

AFRICA'S MOST LETHAL

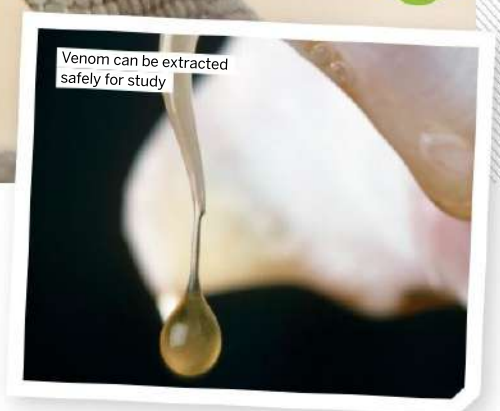
The black mamba (*Dendroaspis polylepis*) can kill a person with just two drops of venom. Named for the dark, inky colour inside of their mouths, black mambas are actually brownish in colour. They average around 2.5 metres in length, and can move at 12 miles per hour. These lengthy snakes are born with two to three drops of venom in each fang, so they are lethal biters right from birth. By the time they reach adulthood, they can store up to 20 drops in each of their fangs. Without treatment, a bite from this African snake is just about always fatal.

Once injected, the venom interferes with activity at a junction where nerves and muscles connect, resulting in paralysis. Because the venom is also cardiotoxic, it can lead to cardiac arrest. Scientists aren't sure exactly how many people are killed every year by black mambas, but they're estimated to be responsible for the largest number of snake-related deaths in southern Africa.

Find me here
Africa

Black mambas are among the fastest snakes in the world

Did you know?
Around 600 species of snakes are venomous



Venom can be extracted safely for study

Find me here
India

INDIA'S 'BIG FOUR'

These species pose the biggest threat to humans in the Indian subcontinent

Russell's vipers can grow to be two metres long

1 Russell's viper

This snake is responsible for the majority of snakebite deaths in India. In Sri Lanka, this nocturnal viper likes to rest in paddy fields, causing high mortality among paddy farmers during harvest time. The snake's venom can lead to acute kidney failure, severe bleeding and multi-organ damage.

The saw-scaled viper is the smallest of the 'Big Four'

2 Saw-scaled viper

Rather than the stereotypical 'hissing' sound attributed to snakes, this viper starts 'sizzling' by rubbing together special serrated scales when threatened. A bite can cause localised swelling and pain, followed by potential haemorrhage and ultimately acute kidney failure. There are nine types of antivenom for this snake.

The Indian cobra spreads the hood around its head to appear more threatening

3 Indian cobra

Often seen with snake charmers, these deadly cobras – also known as the spectacled cobra, Asian cobra or binocellate cobra – can vary in colour and pattern. Typically, this snake will bite at night, with the venom released causing internal bleeding. The solitary predators are often found in tree hollows and within rocky terrain.

The common krait can be active during both the day and night

4 Common krait

The common krait usually tries to avoid light and humans. When this snake does attack people, it releases extremely potent venom with presynaptic neurotoxins. This paralyses muscles, controlled by the central nervous system. Many victims can survive because the venom is unable to stop the heart directly.

© Alamy / Getty

MIGHTY KING COBRA

How venom is released by this hooded snake

Find me here
South Asia

VENOM GLAND
Venom is produced in this evolved salivary gland.

COMPRESSOR MUSCLE
This muscle surrounds the venom gland. When this contracts, the gland is squeezed and venom is pushed out.

VENOM DUCT
This duct serves as a passageway, carrying venom from the gland to the fang.

PROTECTIVE SHEATH
The snake's fragile fangs are protected by the surrounding skin.

FANGS
At eight to ten millimetres, a king cobra's fangs are relatively short. This is because they are fixed to the upper jaw.

King cobras have distinguishing neck patterns

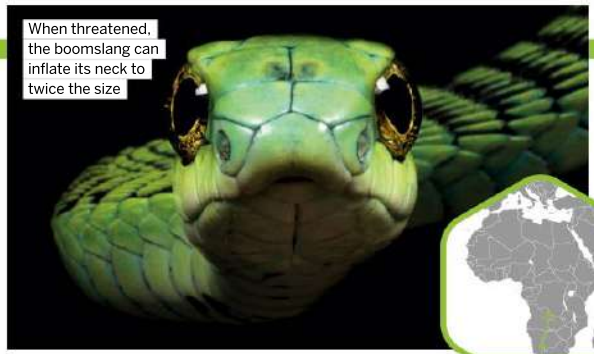
Find me here
Southeast Asia

BREATHTAKING BANDED KRAIT

The banded krait (*Bungarus fasciatus*) is a slow mover during the day and is much more likely to bite after dark. The snake's venom can paralyse muscles and prevent the diaphragm from moving. This stops air from entering the lungs, effectively resulting in suffocation. The banded krait is found on the Indian subcontinent and in Southeast Asia. Its striking yellow and black striped body is easily recognisable, as well as its yellow arrow-shaped marking on its head.

The banded krait is named for its black and yellow bands

DID YOU KNOW? A single bite from a king cobra can kill a human in 15 minutes, and an elephant in just a few hours


When threatened, the boomslang can inflate its neck to twice the size

Find me here
Africa

REAR-FANGED BOOMSLANG

About 24 hours after being bitten on the thumb by a juvenile boomslang in 1957, herpetologist Karl Patterson Schmidt died from internal bleeding from his eyes, lungs, kidneys, heart and brain. Like many others in the field at the time, Schmidt believed that rear-fanged snakes like the boomslang (*Dispholidus typus*) couldn't produce a venom dose big enough to be fatal to humans. But he was dead wrong.

The boomslang, which can be found throughout Africa but lives primarily in Swaziland, Botswana, Namibia, Mozambique and Zimbabwe, is one of the most venomous of the so-called rear-fanged snakes. Such snakes can fold their fangs back into their mouths when not in use. As with other deadly snakes, this one has hemotoxic venom that causes victims to bleed out internally and externally.

THE FIERCE FER-DE-LANCE

A bite from a fer-de-lance (*Bothrops asper*) can turn a person's body tissue black as it begins to die. These pit vipers – which live in Central and South America, grow to between 1.2 and 2.5 metres long and weigh up to six kilograms – are responsible for about half of all snakebite venom poisonings in Central America. Because fer-de-lance venom contains an anticoagulant – a substance that hinders blood clotting – a bite from this snake can cause a person to haemorrhage. A single female can give birth to 90 offspring, each with a potential life span of over 20 years.

Fer-de-lances are patterned with black diamonds with light borders

WORLD'S MOST VENOMOUS

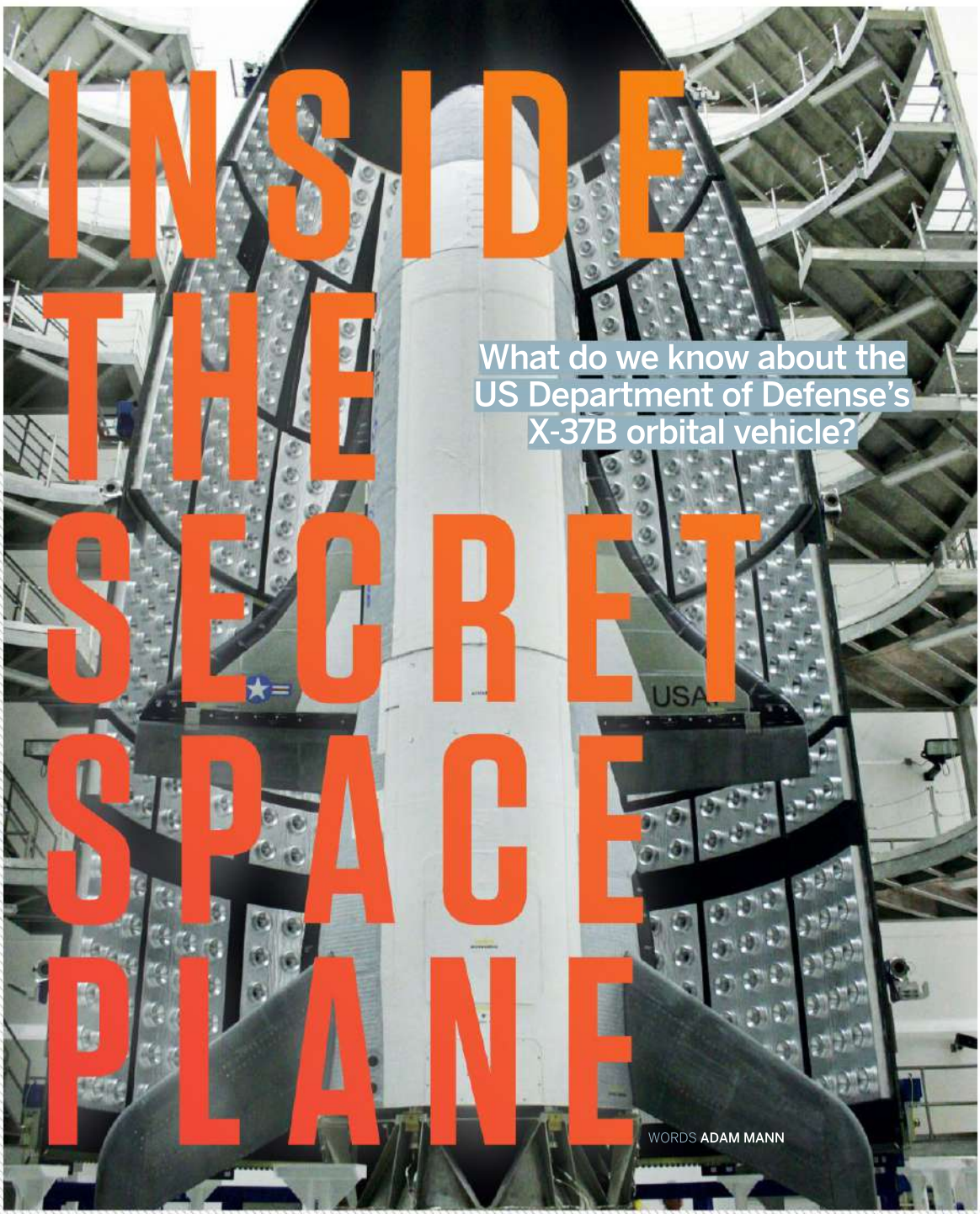
The inland taipan is one of the most venomous snakes, meaning just a teensy bit of its venom can kill prey... or human victims. They live tucked away in the clay crevices of Queensland and South Australia's floodplains, often within the predug burrows of other animals. Living in more remote locations than the coastal taipan, the inland taipan rarely comes into contact with humans, favouring a quick getaway over a defensive strike.

When the taipan feels threatened, the snake coils its body into a tight S-shape before darting out in one quick bite or multiple bites. The main component of its venom, which sets it apart from other species, is the hyaluronidase enzyme. This enzyme increases the absorption rate of the toxins throughout a victim's body.

Did you know?
The saw-scaled viper is very likely to bite

Inland taipans are most common in the Australian outback

© Alamy / Getty / Illustration: The Art Agency: Sandra Doyle



INSIDE THE SECRET SPACE PLANE

What do we know about the US Department of Defense's X-37B orbital vehicle?

WORDS **ADAM MANN**

DID YOU KNOW? The X-37B was awarded the Collier Trophy, a most prominent aviation award, for its contribution to space travel

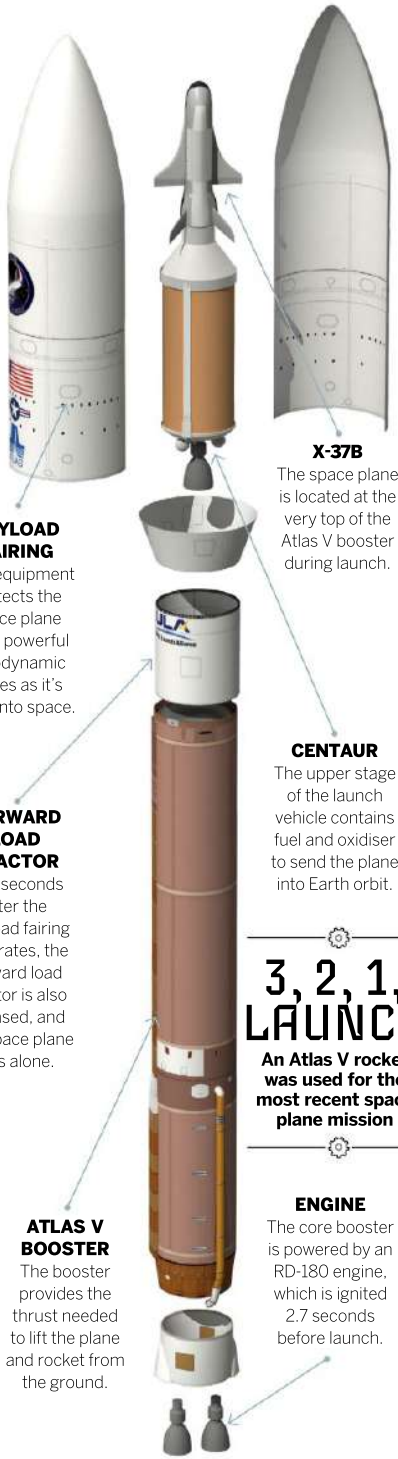
Did you know?
The plane can change orbit patterns by flying low

The design improves on the Space Shuttle

The uncrewed X-37B spy plane is one of the most intriguing spacecraft in the world, flying regular covert missions whose purposes aren't fully known. However, over the years more information about the craft, which is also known as the Orbital Test Vehicle (OTV), has come to light one tidbit at a time. The reusable craft, resembling a smaller version of one of NASA's now-retired Space Shuttles, was originally built by NASA in 1999. It's around 8.8 metres long and 2.9 metres tall, with a wingspan of slightly less than 4.6 metres. It weighs 4,990 kilograms when on the launchpad.

Like the Space Shuttles before it, the X-37B takes off vertically and is propelled by a rocket. Once in orbit, it can manoeuvre on its own, and it eventually lands on a runway back on Earth, much like a conventional plane. The vehicle has a small payload area – roughly the size of a pickup truck bed – enabling it to carry gear and satellites. It operates at altitudes between 110 and 500 miles above Earth. NASA transferred two X-37B vehicles to the Pentagon's Defense Advanced Research Projects Agency (DARPA) in 2004. After being operated by the US Air Force for many years, the robotic spy planes came under the purview of the newly established Space Force in 2020.

An X-37B stored in a hangar



PAYLOAD FAIRING
This equipment protects the space plane from powerful aerodynamic forces as it's fired into space.

X-37B
The space plane is located at the very top of the Atlas V booster during launch.

FORWARD LOAD REACTOR
Five seconds after the payload fairing separates, the forward load reactor is also released, and the space plane flies alone.

CENTAUR
The upper stage of the launch vehicle contains fuel and oxidiser to send the plane into Earth orbit.

3, 2, 1, LAUNCH
An Atlas V rocket was used for the most recent space plane mission

ATLAS V BOOSTER
The booster provides the thrust needed to lift the plane and rocket from the ground.

ENGINE
The core booster is powered by an RD-180 engine, which is ignited 2.7 seconds before launch.

X-37B MISSIONS

PLANE DEBUT
In April 2010, the space plane was launched into orbit, where it remained for 224 days. This mission was called OTV-1, short for Orbital Test Vehicle 1.

DOUBLE TIME
The OTV-2 mission was launched using a different X-37B. This mission lasted over twice as long as the first, totalling 468 days and beginning in March 2011.

RETURN TO THE ORIGINAL
OTV-3 saw the use of the same plane as OTV-1. It flew for 674 days between December 2012 and October 2014.

SMOOTH LANDING
OTV-4 began on 20 May 2015, using the same plane as OTV-2. It spent 718 days in space before performing the first X-37B landing at NASA's Shuttle Landing Facility in Florida.

FALCON 9 LIFTOFF
On 7 September 2017, OTV-5 was launched from NASA's Kennedy Space Centre, returning 780 days later. It carried experiment apparatus to test oscillating heat pipe technologies in space conditions.

2020 MISSION
The latest mission was launched on 17 May 2020 using the Atlas V. This was the first to carry an added experiment module to increase its productivity.

© Getty

WHAT'S IT UP TO?

Despite flying six missions, its true purpose remains a mystery. Some possibilities include surveillance of Earth's surface and deploying spy satellites, though nothing has been confirmed. More out-there theories have been proposed, such as the notion the X-37B could be a space-based bomber, a vehicle for spying on the Chinese space station or a means for the US military to interfere with other countries' satellites. Experts have splashed cold water on all these ideas, saying they would require large amounts of fuel or would be too easy to trace back to the US military.

Technicians carry out checks on Orbital Test Vehicle 1

EXPERIMENT MODULE

Shortly before the most recent X-37B launch, the US military revealed the spy plane had a new service module that allowed for large numbers of experiments to be carried to orbit. The mission deployed a small satellite known as FalconSAT-8, containing five experimental payloads, some developed by the US Air Force and some by NASA. While NASA has stated that it was flying an experiment on a previous X-37B flight, this was the first time the military had disclosed any specifics about such cargo.

The new experiment module is seen attached to the outside of the plane.

The X-37B is enclosed in the protective payload fairing

Did you know?
The X-37B can be launched by different rockets

ADVANCED TECHNOLOGY

The instruments and materials that make the X-37B's mission goals achievable

AVIONIC EQUIPMENT
The space plane has an autonomous guidance system. Its avionics allow the vehicle to deorbit and land without a crew.

JET FUEL TANK
The fuel tank at the front of the plane is filled with kerosene. Kerosene is a compact fuel and can withstand extreme temperatures.

MANOEUVRING THRUSTERS
Electric thrusters are used to move the plane while in orbit.

DID YOU KNOW? The X-37B and the Space Shuttle are the only planes to have entered service, to date

LARGE FUEL TANK
The largest fuel tank is found at the rear of the plane. This holds hydrogen peroxide.

MAIN ENGINE
The plane's engine was designed to run for a period of nine months.

FLAPERON
Sections of the wings can be tilted to stabilise the plane during lower speed flying, such as landing.

EXPERIMENT BAY
This empty bay can be filled with experiments and other equipment, adding versatility to each flight.

The Atlas V is a dependable rocket responsible for many successful spacecraft launches since its inaugural flight in 2002

A concept of the plane in Earth orbit

"The vehicle has a small payload area – roughly the size of a pickup truck bed – enabling it to carry gear and satellites"

© U.S. Air Force / Getty

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A: UNFAMILIAR FLYING OBJECT B: UNIDENTIFIED FLYING OBJECT C: UNKNOWN FLOATING OBJECT

Enter online at **howitworksdaily.com** and one lucky entrant will win!

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OFFER EXPIRES 31 DEC 2021

MEET THE EXPERTS
Who's answering your questions this month?

Jo Elphick
History and forensic science

Andy Extance
Chemistry, tech and science

Andrew May
Space, transport and science

Victoria Williams
Animals, the environment and science

Would a dinosaur steak taste like chicken?

Kendra Jefferies

Dinosaurs were closely related to birds, so they probably tasted like them. But different birds have different flavours depending on activity and diet, and so would dinosaurs. Small herbivorous ones might have tasted like chicken, but a *T. rex* steak would probably taste more like an eagle or similar predator. **AM**

WHEN AND WHERE WAS THE FIRST MOTORWAY BUILT?

Andy Masons

Mechanical engineer Piero Puricelli created the first motorway in 1924. It stretches from Milan to Varese in Italy, and is known as the 'Motorway of the Lakes'. **JE**

IS MOULDY BREAD BAD FOR YOU?

Jak Bender

You might have an allergic reaction or breathing problems if you eat it. Cutting out the mould might not work, as it sends roots through soft food like bread. **AE**

By 1922, the United Kingdom had become what we know today

When was the United Kingdom formed?

Louise Allen

The UK was formed over a long period of time. In 1707, under the Acts of Union, the Kingdom of Scotland joined with the Kingdom of England, which already included Wales, forming the Kingdom of Great Britain. In 1801 the Kingdom of Great Britain and Ireland was created when Ireland decided to join the union, but this all changed in 1922 when Éire withdrew, leaving only Northern Ireland as part of the UK. **BB**

Dark matter fills the universe with invisible mass

What is dark matter made of?

Nicole Traynor

No one knows. The only certain fact is that it isn't made of the same atoms as ordinary matter. It must be some exotic type of particle not yet discovered. **AM**

Did you know?

Penicillium gives bread a blue-green coating

© Alamy / Getty

WHY DO DIFFERENT COUNTRIES HAVE DIFFERENT ELECTRICAL SYSTEMS?

Marissa Christian

It's mostly to do with when they were built. The main difference is voltage, which measures how hard electricity pushes through wires. Higher voltage networks should be cheaper, as the wires needed can be thinner. For example, the older US network has a lower voltage than more recent European ones. **AE**

Don't forget an adapter when travelling

Did you know?
1G commercial networks were launched in Japan in 1979

This plant's cavity is full of digestive fluid

What's the biggest creature a carnivorous plant will eat?

Mila-Rose Dyer

Carnivorous plants usually live on a diet of insects and other invertebrates, but some have been discovered with the remains of lizards and frogs in their traps. The world's largest meat-eating plant is *Nepenthes rajah*, a pitcher plant native to Borneo. Its pitcher is so big that it occasionally traps rats. **VW**

CAN YOU STILL DIE FROM COVID-19 AFTER GETTING THE VACCINE?

Stephen Conn

Sadly, yes, although it's unlikely. Statistics released by Public Health England revealed that 117 people died from the Delta variant between February and June 2021: 44 had not been vaccinated, 20 had received one dose and 50 had received both doses. The vaccine status of the remaining three was unknown. Initially it looks as if the vaccine isn't effective, but this isn't the case. The government ensured that the elderly and most vulnerable members of society were vaccinated first, which means that those who had been double jabbed were more likely to die from the disease anyway. **JE**

Getting the vaccine is still the safest way to protect yourself against COVID-19

Did you know?
Henry Ford gave employees the first official weekend off

IS 5G SAFE?

Jenna March

There's no evidence that 5G signals are harmful. Public Health England, the UK Health Protection Agency and the World Health Organization have led studies that show 5G has no effect on human health "if exposures are below international guideline levels". Anywhere above these levels, such as close to the base stations where 5G signals are amplified and emitted, is always shielded or closed off to the public. **BB**

WHY ARE WEEKENDS THE SAME FOR MOST PEOPLE?

Kelly Longman

During the Industrial Revolution, Christian Britain considered Sunday to be a holy day, designed to pray. But Jewish workers observed the Shabbat, which fell on a Saturday. This caused a problem for factory owners. By giving workers two days off, everyone was happy and absences decreased. **JE**

How far out could a planet's orbit be from our Sun?

Robbie McKenzie

For a planet to orbit the Sun, it must be gravitationally bound to it, so it has to be close enough to feel the Sun's gravity more strongly than that of any other star, and to travel slower than escape velocity from the Sun at that distance. We know that objects in the Oort Cloud, up to two light years out, orbit the Sun, so a planet at that distance likely would too. **AM**

A planet could be way out in the Oort Cloud and still orbit the Sun

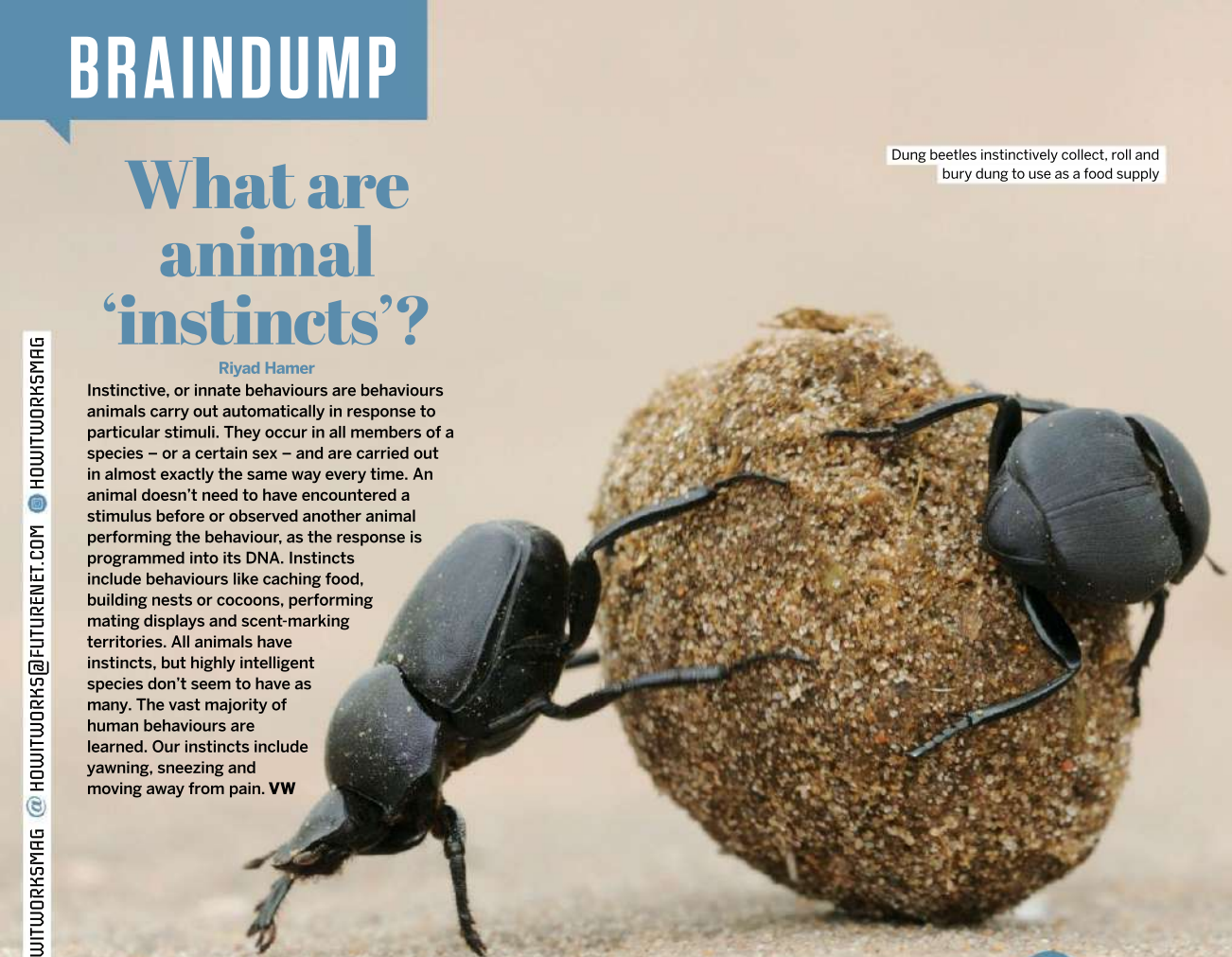
Did you know?
The Oort Cloud is a thousand times farther than Neptune

© Getty / Alamy

What are animal 'instincts'?

Riyad Hamer

Instinctive, or innate behaviours are behaviours animals carry out automatically in response to particular stimuli. They occur in all members of a species – or a certain sex – and are carried out in almost exactly the same way every time. An animal doesn't need to have encountered a stimulus before or observed another animal performing the behaviour, as the response is programmed into its DNA. Instincts include behaviours like caching food, building nests or cocoons, performing mating displays and scent-marking territories. All animals have instincts, but highly intelligent species don't seem to have as many. The vast majority of human behaviours are learned. Our instincts include yawning, sneezing and moving away from pain. **VW**



Dung beetles instinctively collect, roll and bury dung to use as a food supply

Did you know?
Male mice woo mates by singing ultrasonic songs

IS IT POSSIBLE TO TAKE CARBON DIOXIDE BACK OUT OF THE ATMOSPHERE?

Shakeel Kumar

Yes, it is, and chemical 'carbon dioxide (CO_2) scrubbers' are essential items in closed environments like spacecraft and submarines to prevent the buildup of toxic CO_2. In the natural world, trees and other plants constantly extract CO_2 from the atmosphere via photosynthesis. Even so, they're fighting a losing battle against all the CO_2 emissions humans are responsible for. Many people believe that in the future we will need new technologies – such as the 'direct air capture' method currently being tested – that are capable of removing CO_2 on an industrial scale. **AM**

A prototype direct air capture system in British Columbia, Canada

HOW MUCH DOES A CLOUD WEIGH?

@jonesy_rhys06

Despite their cotton-like appearance and the ease at which an aeroplane flies through them, an average fair-weather cumulus cloud with a volume of 0.23 cubic miles can weigh in at 500,000 kilograms. This is about four times as heavy as a blue whale – and that's only counting the water particles that the cloud is made up of. Big, dark storm clouds, called cumulonimbus, can weigh much more than that. **BB**

Even small clouds can weigh hundreds of tonnes

Recycling electronic waste doesn't often give back pure elements

Could we ever run out of the rare elements used in today's electronics?

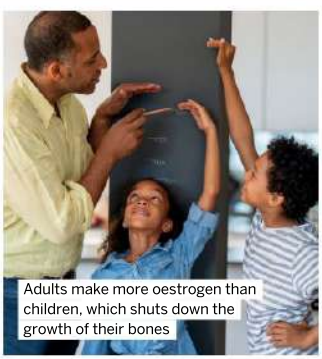
Mikey Simons

The rare elements that go into electronic devices don't disappear when we throw them away. They are still there in the devices. If we still need them and we can't easily mine them, we can try to recycle them from the old devices. That's where the problem comes in, as there isn't much recycling of the rare elements yet. Recycling probably won't become more common until the elements become very rare, and therefore very expensive. **AE**

WHY DO HUMANS STOP GROWING AS ADULTS?

Rianne Iles

You're probably referring to the fact we all stop getting taller in early adulthood. Children grow taller because their bones get longer via growth plates at their ends. When we finish puberty and enter adulthood, both men and women start producing more of the hormone oestrogen. This higher oestrogen level shuts down the growth plates and stops our bones getting longer. But our ears and noses never stop growing. Rather than bone, they are soft tissue and cartilage. Some scientists think cartilage cells keep on growing. Others think that gravity's pull tugs away forever, lengthening these features all through our lives. **BB**



Adults make more oestrogen than children, which shuts down the growth of their bones

CAN VETS TREAT HUMANS AS WELL AS ANIMALS?

Anastazja Knapp

Vets have a wide set of skills and knowledge, often treating several species in a day. But there's one they can't treat: humans. A vet's licence to practice doesn't cover people. In an emergency they might be able to transfer their knowledge to a human casualty. As long as it can be classed as first aid and not treatment, they're protected in some countries by 'Good Samaritan' laws. **VW**

WHAT'S THE OLDEST SPECIES STILL ALIVE TODAY?

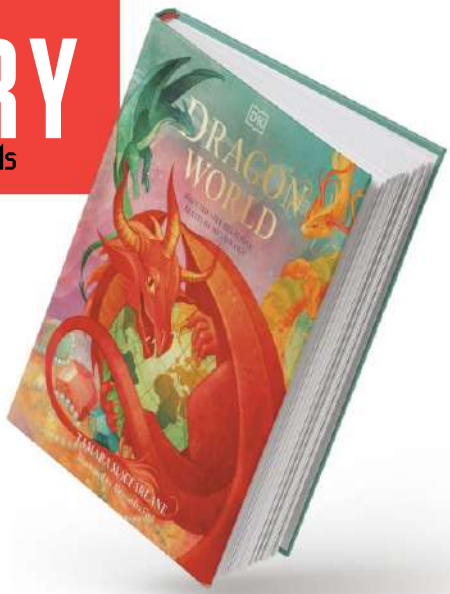
Duncan Cobb

Cyanobacteria are believed to be the oldest group of species that still exists on Earth. These microorganisms have been around for at least 2.1 billion years – some scientists think it's more like 3.5 billion. **VW**

© Alamy / Getty

THE LIBRARY

The latest book releases for curious minds



DRAGON WORLD

THESE FIRE-BREATHING BEASTS HAVE MUCH KNOWLEDGE TO IMPART

AUTHOR **TAMARA MACFARLANE**
ILLUSTRATOR **ALESSANDRA FUSI**
PUBLISHER **DK CHILDREN**
PRICE **£9.99 / $17.99**
RELEASE **OUT NOW**

Dragons were popular long before Daenerys Targaryen mounted Drogon in *Game of Thrones* and turned the Lannister supply lines into strips of bubbling metal and ash; long before *How to Train Your Dragon* inspired a generation of kids to dress puppies in wing costumes, before *Pete's Dragon* gave imaginary friends scales and fangs and even before Tolkien made them the supremely intelligent beings of high fantasy that we're familiar with today. Under the banner of quality illustrated reads that is DK, author Tamara MacFarlane has written a book about dragons that's guaranteed to capture the imagination of any child.

The focus of *Dragon World* is on real dragon mythology from almost every civilisation that features these fantastic creatures. Much of Asian culture is steeped in dragon legends, so there's a good third or so of this 80-page book that's dedicated to exploring dragon tales from Japan, China and India, describing famous named dragons like Naga and Orochi. European dragons also have a large and dedicated section, with stories such as Y Ddraig Goch – how the Welsh flag came by its unique red dragon emblem. The rest of the world is a little more sparse in its dragon mythology, although there are distinctive stories from Australia and the tribespeople of the Arctic Circle. The pleasantly surprising part of *Dragon World* comes at the end with Dragon Discoveries, which dresses up science and nature as fun fantasy fiction. Readers will learn about 'dragon jewels' - precious and semi-precious stones, where dragons live within layers of the Earth, living dragons, which are animals named after dragons, and even dragon science – animals with dragon-like abilities explained.

A book about dragons that's guaranteed to capture the imagination of any child

Illustrator Alessandra Fusi even gets to contribute to *Dragon World* beyond her fantastic artwork. In the final few pages, there's a guide on how to draw and design a dragon for your own work of fantasy. We didn't imagine for a second that this could be a mythology, history, science and art lesson all in one book, but that's what *Dragon World* is.

MICROBE WARS

HUMANITY'S BIGGEST BATTLES WITH THE WORLD'S SMALLEST LIFE FORMS

AUTHOR **GILL ARBUTHNOTT**
ILLUSTRATOR **MARIANNA MADRIZ**
PUBLISHER **TEMPLAR PUBLISHING**
PRICE **£14.99 (APPROX. $20.40)**
RELEASE **OUT NOW**

If you're looking for a way to explain the global pandemic to your children, this book is a must. Funny, informative and brilliantly illustrated, *Microbe Wars* explains not just the science behind COVID-19, but journeys back in time to some of the biggest outbreaks in history. This book is a melting pot of information surrounding the microbial world, including the different types of microbes, their role in the world – both bad and good – and how your immune system and vaccines work. Comical illustrations bring some levity to a science-heavy and frequently serious subject.

Microbe Wars is a testament to the author's dedication to informing a young audience, as pages are packed with answers to questions that children are currently asking about the pandemic and beyond.

HOW TO SAVE OUR PLANET

THE HARD FACTS ABOUT EARTH AND CLIMATE CHANGE

AUTHOR **MARK A. MASLIN**
PUBLISHER **PENGUIN LIFE**
PRICE **£7.99 / $9.99**
RELEASE **OUT NOW**

As a frank and relevant book on climate change, *How To Save Our Planet* strips away the soft, cushioning language about the state of our climate and presents blunt facts about how we got to where we are and how we can prevent further problems. This book is a refreshing read when it comes to talking about climate change and the environment. If you ever find yourself in a verbal tussle with a climate change denier, this is the book you need in your pocket. Packed with figures and statistics that would inform discussions not only around a table, but across the aisle in parliament, Maslin outlines the political and economical changes that need to be made by governments around the world to tackle climate change, predicting that "the challenge of the 21st century is that we must learn to think and act as a global species."

WELCOME TO THE FUTURE

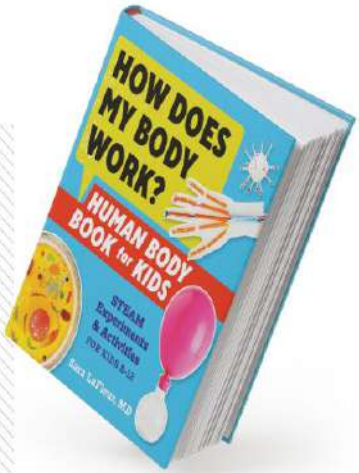
TEN FUTURISTIC TECHNOLOGIES

AUTHOR **KATHRYN HULICK**
ILLUSTRATOR **MARCIN WOLSKI**
PUBLISHER **FRANCES LINCOLN**
PRICE **£14.99 / $24.99**
RELEASE **OUT NOW**

What does the future look like? It's easy to imagine a world where technology does almost everything for us, but how realistic is this image? A multitude of futuristic technologies have been envisaged in science fiction, but as technology advances in the real world, some of these ideas are coming closer to reality than others.

Welcome to the Future has been written with the perfect balance of fantasy and science. Immersing the reader into a seemingly impossible scene at the start of each chapter, Hulick goes on to pick apart the elements that are more plausible. Will genetic modifications lead to real-life superheroes? And how are new inventions enabling us to control technology with the power of our minds? This book not only reminds you of the constant evolution of technology, but also brings awareness to some of the latest global experiments taking place today.

But just because you can do something doesn't mean you should. *Welcome to the Future* explores some of the issues that new technology can bring, from the risks of living on another planet to the moral dilemma that comes with creating pet dinosaurs. Which of these ten technologies would you keep?



HOW DOES MY BODY WORK?

THE HUMAN BODY BOOK FOR KIDS

AUTHOR **SARA LAFLEUR**
ILLUSTRATOR **DIEGO VAISBERG AND MARTIN LOWENSTEIN**
PUBLISHER **Z KIDS**
PRICE **£10.99 / $11.99**
RELEASE **OUT NOW**

The human body is a complex network, with ten major systems working together to keep us alive. The best way to understand how these work is through a combination of information and experiments. This hands-on book provides exactly that, packed with more than 40 STEAM experiments and activities suitable for children aged 8 to 12. Some of these activities include taking on the role of a heart with your homemade heart pump model and extracting DNA from cells as you learn about the unique codes that make you, you. When carrying out these experiments, there are clear step-by-step and photographic guides to follow alongside scientific explanations for your results.

This book is written with children in mind, so there are plenty of relatable analogies that will help to make the scientific processes more memorable. Accompanying the text, stimulating illustrations combine cartoon imagery and informative diagrams, allowing the reader to visualise their own detailed anatomy. Between learning some of the basic functions of the body, fascinating fact boxes are dispersed throughout. In these you can expect to learn the most surprising details about your body.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		5	2	1				
			4		5	9		
4	8	9						2
9	5	1	7	4	2			
	6			9		2		1
2	7			3			9	5
8			9			5	4	6
			8			7	1	3
5		3	1	6			2	9

MEDIUM

	1	7	2					
				4	3			
9				6		5	3	
8	9			3	7	6		
5							1	
4	7	2	1		6		5	
	2	5			9		7	
	3		6		5			
	8		3				4	5

HARD

		9		8		3		
8				6				5
		2	7			1		
	7				9		4	8
		5	4					
2	6				8			7
					6	4		
1				7				
			8			9	1	

Word search

Find the following words

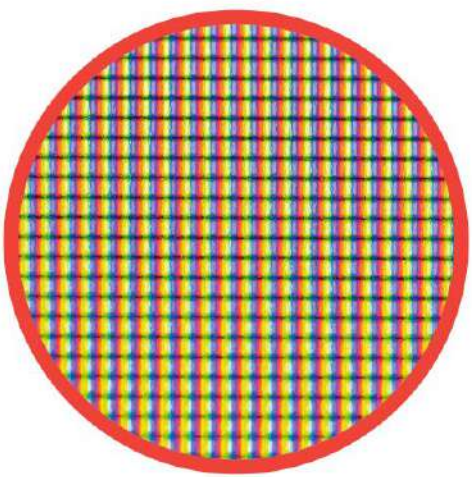
UFO
ELECTRICITY
DARK
COAL
LUMINOL
HEART
MARS
SOUND
CUP
GOVERNMENT
PLANE
PLASMA

U	O	F	U	D	Y	M	K	O	B	J	E	N	U	H
M	A	R	Z	A	S	O	U	L	R	A	I	M	E	I
J	F	E	P	K	L	A	S	U	M	A	G	A	U	E
G	O	L	V	R	E	Y	K	M	G	H	R	R	X	O
H	Y	E	L	O	V	R	E	I	R	T	O	S	E	M
T	E	C	O	L	A	N	T	N	E	A	R	B	I	D
N	O	T	L	D	U	E	N	O	L	P	E	A	R	T
E	Q	R	L	K	A	T	Z	L	M	O	R	C	J	X
M	S	I	T	S	O	B	E	L	U	N	I	N	E	B
N	D	C	U	P	O	U	N	B	L	A	N	E	N	Y
R	P	I	L	A	X	S	O	N	J	C	E	D	A	P
E	A	T	R	H	M	P	L	A	S	M	A	N	L	V
V	R	Y	U	E	T	X	E	S	N	I	A	L	P	O
O	Y	K	J	W	S	O	U	N	D	I	Y	R	O	L
G	V	O	L	S	M	A	E	N	T	C	O	A	L	W

What is it?

Hint: It takes millions of these to make a digital image

A



Spot the difference

See if you can find all six changes between the images below

QUICKFIRE QUESTIONS

Q1 Where is the infamous 1947 'UFO' crash site in the US?
- Roswell, New Mexico
- Birmingham, Alabama
- Reno, Nevada
- Anchorage, Alaska

Q2 Which Bond film did Snooper the robot appear in?
- *Moonraker*
- *A View to a Kill*
- *Casino Royale*
- *Tomorrow never Dies*

Q3 Which communist leader ruled Soviet Russia from 1924 until 1953?
- Karl Marx
- Vladimir Lenin
- Joseph Stalin
- Nikita Khrushchev

Q4 What is the name for a unit of electrical resistance?
- Volt
- Ampere
- Coulomb
- Ohm

Q5 What is peat made of?
- Decaying vegetation
- Compressed rocks
- Ancient sea creatures
- Cowpats

Q6 Which video game company started as a playing card manufacturer in 1889?
- Nintendo
- Atari
- Sega
- SNK

Answers

Find the solutions to last issue's puzzle pages

Q1 HARALD HARDRADA
Q2 INFRARED
Q3 1,300
Q4 BASIC INPUT/OUTPUT SYSTEM
Q5 1796
Q6 1,500 KILOGRAMS

What is it?

DRAGONFLY

Spot the difference

© Getty

TURN A PENNY GREEN

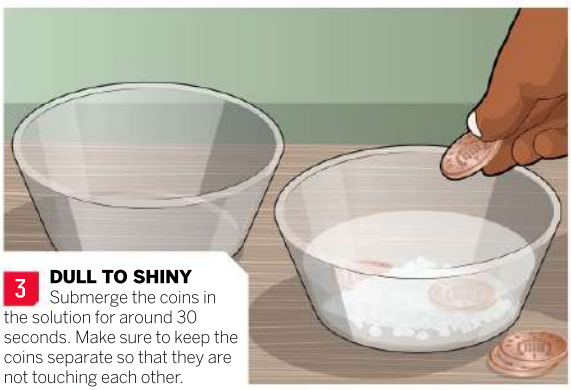
Transform your loose change overnight with the chemical power of kitchen ingredients

KIT LIST

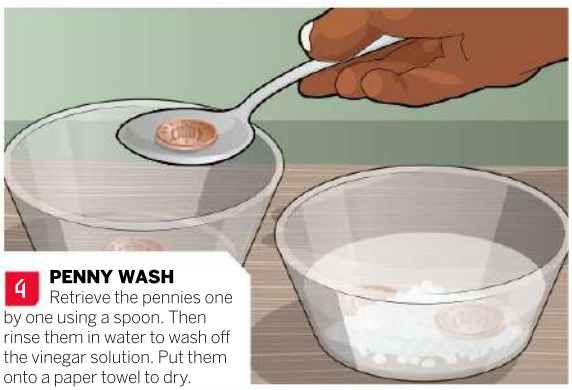
- Three dirty pennies
- 60ml white vinegar
- One teaspoon salt
- Three cotton pads or paper towels
- A small bowl (not metal)
- A small container and lid (not metal)

1 GATHER YOUR EQUIPMENT
Look for the dirtiest, most tarnished coins for the best results. The materials used in this experiment will work on any coins made of copper.

2 ADD THE CLEANERS
Put the salt and vinegar into your bowl. Stir them together until the salt has fully dissolved.



3 DULL TO SHINY
Submerge the coins in the solution for around 30 seconds. Make sure to keep the coins separate so that they are not touching each other.



4 PENNY WASH
Retrieve the pennies one by one using a spoon. Then rinse them in water to wash off the vinegar solution. Put them onto a paper towel to dry.

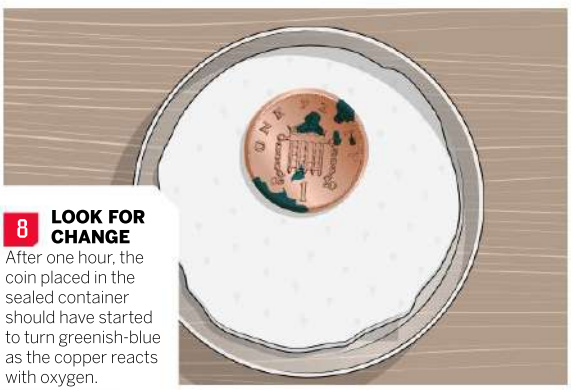
5 FORM A BASE
Take your paper towel or cotton pad, then cut it so that it fits neatly into the bottom of your container. You'll need three bases.

6 CONCEAL THE COIN
Place one penny into the container. Wet the coin and material at the bottom of the container with a few drops of vinegar and cover it with the lid.

NEXT ISSUE
MELT ICE WITH NO ADDED HEAT

DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you

7 CREATE COMPARISONS
Place your remaining coins on the other two pieces of paper towel or cotton pad. Use one that has been rinsed, and dip the other back into the salt and vinegar. Don't cover these.



8 LOOK FOR CHANGE
After one hour, the coin placed in the sealed container should have started to turn greenish-blue as the copper reacts with oxygen.

9 CLEAN TO GREEN
How different does your coin look after leaving it overnight? Compare it with the other two coins to observe three stages of tarnishing. The vinegar-covered coin that wasn't covered by a lid should be dark brown, and the rinsed coin untarnished.

SUMMARY

The green money you're left with is the result of a chemical reaction between copper and oxygen. As the copper oxidises – when copper atoms join together with oxygen atoms – its chemical composition is altered. First it develops a copper oxide coating, then another of a green mineral called malachite – the same mineral that turned the Statue of Liberty green.

It takes copper years to achieve this colour naturally, but some conditions can speed the process up. In this experiment, the salt and weak acid (vinegar) solution dissolves the copper oxide layer, making it easier for the exposed copper atoms to react with oxygen in the air. The coin rinsed in water is less prone to oxidation, and thus stays shiny. The vinegar-covered coin that's outside of the container turns brown, but the vinegar dries up before further reactions can take place. Meanwhile, the vinegar-covered coin inside the container stays damp for longer, and the copper oxide transforms into malachite. At the end you are left with coins in three stages of tarnishing.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

THE SPACE BUSINESS

20th-century space exploration may have belonged to state-funded giants like NASA, but with hotels in orbit to mining the Moon, today private enterprise is setting the template for the future

A HOTTER WORLD

Dear **HIW**,
With climate change heating up the planet, what would thrive in a hotter world?
Adrian Fisher

Human activity is the main cause of current global warming

LETTER of the MONTH

Cold-blooded animals are generally slower to adapt to climate change. Because they find it more difficult to adjust their body temperatures, drastic increases are more likely to reduce or wipe out these species. Some species, like plants found in deserts, would likely thrive in a hotter world, as they're designed to be heat tolerant and drought-resistant. Thermophiles – species that have evolved to survive in hot environments, such as volcanic springs – will also be relatively unphased by the heating planet.

Looking to the past, a success story can be found in cockroaches. These insects have survived multiple mass extinctions, living on Earth for over 280 million years.

Scientists believe that older species living in more diverse habitats are most likely to survive, while specialised species living in niche environments will struggle to adapt to warming climates.

Marine life forms found in deep-sea hydrothermal vents receive their energy from Earth's core, rather than the Sun. This means that these species are unlikely to experience changes to the same degree as life nearer the ocean's surface.

PRECISION DRILLING

Oil rigs can be found both onshore and offshore

Dear **HIW**,
How does drilling for oil, gas and water work? I can understand how to drill vertically, but how do they get to a specific point – for example in cave and mine rescue?
Philip

Thank you for your question, Philip. The first task in carrying out precise drilling is to locate the item being extracted. Seismic surveys are carried out to analyse the composition of the ground below. By analysing how vibrations travel through the ground, it's possible to determine where the areas of oil, gas and other materials are.

To reach these underground locations, a main borehole is created vertically before drilling begins horizontally. This is called horizontal directional drilling. It's often used when drilling for oil so that it can be extracted from the most stable entry point.

HISTORY OF THE SEASONS

Dear **HIW**,
The change in season from summer to autumn seems to have happened very quickly. Autumn is very distinctive; it made me wonder, when did people first refer to this time of year as 'autumn'?
Dion Jamini

Autumn has been used to describe this time of year since at least the 12th century in Britain. It was rarely used until the 14th century, and became more common in the 17th century. This season was also called 'fall' in England, in reference to the falling of leaves from deciduous trees at this time of year. During the 17th century, this name for the season caught on in North America, while 'autumn' became more commonplace in Britain. The word 'autumn' is believed to have originated from the Latin word 'augere', which means 'to increase'. The seasons were incorporated into the Gregorian calendar in 1582, as the Roman emperors' previous calendar miscalculated the solar year. This meant that the older calendar didn't line up with the four seasons.

Deciduous leaves turn brown during autumn

NEXT ISSUE ISSUE 158

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A dog may lick you for attention

DOG LICKS

Dear **HIW**,
Why do dogs like to lick people?
Eric Scott

It might seem unusual to a person, but for dogs, their tongues can be used for multiple purposes. Their tongues are used to explore their surroundings using scent and taste. Similarly to how you might explore objects by touching them with your hands, a dog usually does this with its tongue. If a dog is licking you it can also be a sign of affection. When they are puppies, dogs are licked by their mothers as a loving act. Finally, dogs lick when grooming. You will also see dogs lick themselves. Their tongues are covered in antibacterial saliva, and licking is a sign of cleanliness.

Netflix also displays the most popular shows on its homepage

RECOMMENDED FOR YOU

Dear **HIW**,
How does Netflix work to find other shows and films that you will like? How are they categorised to find similar titles?
Olivia Sutton

When logging in, users are presented with a list of titles that are tailored to their interests. The more you watch, the more Netflix can deduce about your viewing preferences. This list is created using Netflix's algorithm. The information logged into this algorithm include genres, categories, actors and release years for the titles you watch. If you want to better tailor your recommended viewing, you should rate each film or show after watching so Netflix knows what you like and dislike.

WE ASKED YOU

This month on social media we asked you:

What do you think UFO sightings are?

@LOUISTYNDALL
Could be doctored photos that people create to scare/excite people about aliens

@TIRA.__.MISU
Could be actual UFOs or someone hallucinating and the media going crazy over it

@JAMES_SHEPPARD_PHOTOGRAPHY
Actual craft from a potentially different universe that are visiting, nixing the Fermi paradox

@RYAN_BURNSS
Visual phenomenon, hallucinations

@SULLI.BERRY
Time travellers

@SHRFH_MRYM_SHHB
From another realm

@SCIMAXFACTS
I think that UFOs are either an aircraft or possibly just an asteroid in the sky

@JAMESF_2005
Human-made aircraft

@MONTY_THE_XVI
Weather phenomena

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Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk
Tel: 0203 787 9001

ISSN 2041-7322

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FAST FACTS

Amazing trivia that will blow your mind

10 MILLION

You'd have to eat a lot of bananas at once to die of radiation poisoning

100 MEGATONNES OF TNT

A single solar flare releases an enormous amount of energy

25x

Iceland has more puffins than people

3 BILLION

Our bodies contain a huge number of base pairs of DNA

Rats laugh when they're tickled

12.4 BILLION MILES

Humans have sent probes a vast distance into space

15 MILES PER HOUR

The UK's first police car chase was slower than the average Olympic sprinter

BUILDERS USED STICKY RICE TO CEMENT THE GREAT WALL OF CHINA TOGETHER

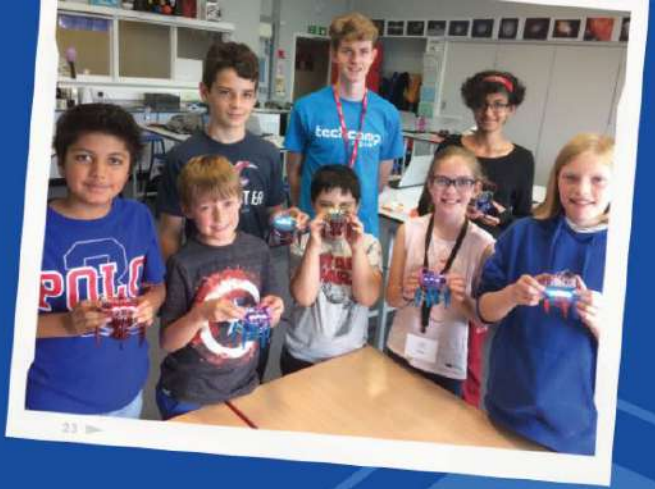
HUMAN STOMACH ACID CAN DISSOLVE METAL

60 METRES

The distance a human sneeze can travel

3 MILLION HOURS

Disney's *Frozen* took over four average human lifetimes to complete



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BLOOD RED SKIES

A Tabletop Game of World War II Fighter Combat

BATTLE OF BRITAIN

Tactical level air combat tabletop game for two or more players.

Written by Andy Chambers, Blood Red Skies is a tabletop miniatures game where you take command of a force of fighter aircraft in battle. The emphasis in Blood Red Skies is on action and the game is fast-paced, with no pre-plotting or book-keeping required. A game of Blood Red Skies with two planes per side can be fought in twenty minutes or less.

The 'Airfix Presents Blood Red Skies' box set comes complete with everything you need to get playing the game, and four aircraft: two Supermarine Spitfire Mk IIs and two Messerschmitt Bf109-Es, in 1:72 scale.

Code: **A1500**

Contents:

- 1 x Blood Red Skies Rulebook
- 2 x Airfix Supermarine Spitfire Mk II fighter 1:72 scale plane kits
- 2 x Airfix Messerschmitt Bf109-E fighter 1:72 scale plane kits
- 4 x BRS Advantage Flying Bases
- 2 x Reference Aircraft Cards
- 8 x Combat Dice
- 6 x Pilot Skill Level Discs
- 6 x Boom Chit Tokens
- 6 x Zoom Tokens
- 3 x Cloud / Air Defence Clusters
- 1 x Navigation Calliper
- 1 x Range Finder
- 2 x Movement Templates
- 1 x Set of Measuring and Navigation Tools

BLOOD RED SKIES

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